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AN EXPERIMENTAL ANALYSIS OF THE PROCESS OF RECOGNIZING[1]

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[1] From the Psychological Laboratory of Clark University.

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I. Introductory

This study is concerned with an analysis and description of the process of recognizing. When the preliminary work was begun, the question in the investigator's mind was this: What is the content of the recognitive consciousness? As the investigation proceeded and it became amply evident that the content of the recognitive process, instead of being unique and constant in its character, may vary widely both qualitatively and quantitatively, the problems formulated themselves as follows: What are the mental components which may function as the content of an act of recognition? What is the nature of the functioning of such contents, *i. e.*, in what order do they appear? Is the awareness of familiarity influenced by the relative intensity and duration of different mental events composing the content of the act of recognizing? Is there a difference in the nature of the content, or of its functioning or of both, in the recognizing of relatively novel and of exceedingly familiar stimuli? What is the essential characteristic which gives to the consciousness of familiarity its unique and proper flavor? These are the problems which this investigation was finally designed to attack.

It is a pleasure to acknowledge my debt both to Professor J. W. Baird, who suggested this problem and who has given generously of his time as adviser and as observer, and to the other observers, upon whose faithful work this study is based.

II. Historical

The experimental history of the analysis of the process of recognizing may be said to begin with the Lehmann-Höffding controversy[2] which was opened in 1889 by an article in which Lehmann (25) maintained that recognition is due to association by contiguity. He pointed out that every perception is attended by a number of associated images, and he held that when a given perception is re-experienced, the images formerly associated with it are incited to arousal, the result of such incitement being the experience of familiarity. Lehmann (25 and 26) offered evidence which, he believed, supported this view. He asked seven observers to report whether or not a given odor was known to them, and then to give an account of all the images which were present to consciousness after the presentation of the stimulus. In his four hundred and twenty-eight cases he obtained 84.7 per cent. of recognitions, and 27.6 per cent. of these recognitions were attended by images of the names of the stimuli; 44.9 per cent. were attended by other instantaneously reproduced

[2] E. H. Weber's experiment with visual lengths and weights (Der Tastsinn und das Gemeingefühl, 1851) was not concerned with the nature of the process of recognizing.

images; 5.2 per cent. by images subsequently appearing, and 7 per cent. by no images whatsoever. Lehmann explained the latter cases on the supposition that images had appeared but in such dim and transitory form that they escaped the attention of the observer. Furthermore, he maintained that it was the inciting of associated images, rather than their actual appearance, which gave the characteristic quality of 'known' to any stimulus.

Höffding (35) granted that associations are frequently present in the recognition of objects, but he denied that they are essential to the act of recognizing, for example, to the immediate recognition of a very familiar object. He asserted, on the contrary, that the perception of familiar objects is qualitatively different from the perception of novel objects; and the quality which is immediately present in the former case, he calls the *Bekanntheitsqualität*. This quality of 'known,' Höffding believes to be due to a fusion of the perception with an immediately aroused image of itself,—the fusion differing from an association in that a unitary experience results. This *Bekanntheitsqualität* is to be referred to a physiological basis,—an increased facility of nerve functioning.

Lehmann denies the existence of Höffding's 'immediate' recognition, basing his case on a series of experiments in which he employed different shades of gray. His procedure consisted in displaying a gray momentarily and after a short interval in displaying another. He then asked the observer to determine whether the second gray was or was not identical with the first, and to give an account of the ideas and other contents which had attended his determination. Again, Lehmann found no case of recognition which he believed to be devoid of reproduced images; and again he urges that the inciting of associated images constitutes the essence of recognition.

Höffding (36) answers this article by maintaining that *1.* Lehmann's exposures were made at such short intervals that the 'disposition' set up by the exposure of one gray, if not the image itself, must still be functioning at the time of the second exposure; and *2.* the artificial conditions of the laboratory render the normal recognitive process impossible.

Bentley (42) attempted to determine the status of the image in the functioning of memory. In extended experiments upon visual imagery, he collected evidence which strongly indicates that assured and correct recognitions frequently occur in cases where no image is present. Whipple (23) reached the same conclusion as a result of experiments with clangs and tones.

In Gamble and Calkins' (65) repetition of Lehmann's experiments with odors, they found a lesser percentage of recognitions without reproduced images and a greater percentage of recognitions which were attended by reproduced images than Lehmann had reported, but they conclude that reproduction is not necessary to the process of recognition. Their conclusion is based on the following facts: *1.* correct reproductions are very often present in cases of non-recognition; *2.* associations which were clear enough to be reproduced were not always present in cases where recognition occurred; *3.* in cases where the order was noted, the attendant associations were usually reported as appearing after the recognition.

Severance and Washburn (69) instructed a number of observers to gaze steadily at various familiar words of six letters, and they found that the words soon began to lose all associative power, and hence became meaningless. A little later, they ceased to look familiar, and

finally, even the letters themselves were meaningless marks, conveying no sense of familiarity. The authors conclude that this loss of associative power and finally of all familiarity was due to the induction of abnormal sequences of the processes attended to.

Dearborn (17) employed ink blots as experimental material in an attempt to analyze the awareness of similarity and dissimilarity. One ink blot was selected as a norm, and placed in a frame convenient to the observer's eye. One hundred other blots were then presented simultaneously, the observer being asked to choose the ten which were most like, or most unlike, the norm. After the choice was completed, the observer described how the norm was apperceived and what was its most essential characteristic. The results show the significance of language in the observer's procedure,—criteria of likeness or difference being almost always sharply defined in words. Dearborn concludes that 'feeling' criteria (feelings of likeness or unlikeness) are more accurate than 'conceptual criteria,'—the observer whom he considered most successful having reported such 'feelings.' Dearborn refers feeling of familiarity to ease of following old cerebral paths, and feelings of unfamiliarity to a 'fumbling among the infinite possibilities of cortical routes.'

Using the method of partially learning nonsense syllables, Meumann (21) asked his observers to state, after each reading, whether or not the syllable just read was recognized as having been seen before. A new syllable was ocasionally inserted in the list, as a control. Meumann finds that the impression of 'unknown' is a much more positive and definite experience than is the impression of 'known.' Five factors conduce to this: the sensation of hesitation, shock or weak fright; the interruption of ideation; the consciousness of void or emptiness; the characteristic feeling of unpleasantness; the non-appearance of the usual ideation. The 'feeling of familiarity,' on the other hand, he holds to be a product of: the facilitation of perception; acompanying feelings and organic sensations, carrying pleasantness and relaxed tension; less strained attention; the reproduction of ideas, often dim and scarcely discoverable.

Heine (66) undertook to determine whether subsequent disturbances have a retroactive effect upon recognition as they have been shown to have upon recall. Her method consisted in having her observers learn parallel series of nonsense syllables or four-place numbers, and then she introduced a disturbance by presenting, immediately after the learning, other materials (pictures, numbers, syllables) which were later to be described or reproduced. The recognition-time and the amount recognized both indicate that no retroactive effect took place. Similar experiments dealing with recall, instead of recognition, show the presence of a considerable retroactive disturbance. From these findings, Heine concludes that the factors involved in recall are fundamentally different from those involved in recognition, and that recognition is not dependent upon associative processes.

Meyer (68) set out to ascertain whether 'preparedness' favors the process of recognition as it does the process of reproduction. His method consisted in measuring the relative time and number of correct judgments of 'new' or 'old' when nonsense syllables which had previously been learned were presented in four different ways: an 'old' syllable preceded by its immediate antecedent in the learning series; an 'old' syllable presented alone; a 'new' syllable preceded by an accented syllable of a learned series; a 'new' syllable presented alone. His results show that those syllables which were preceded

by a 'preparing' syllable derive an advantage from that fact. The effect of this 'preparedness' for recognizing in consequence of the presenting of another associated syllable persists through a long expectation period even when other disconnected material intervenes. Meyer interprets the longer reaction-time and the lesser certainty in the case of unfamiliarity as an indication that the consciousness of 'unknown' is merely the absence of the quality of 'known'; and he quotes Meumann (21, p. 39) in support of this position. But instead of regarding unfamiliarity as a negative quality, Meumann holds that the quality of unknown possesses a much more definite character than the quality of known, and he even specifies its characteristics in detail (21, p. 38 ff.).

III. Experimental

A. Preliminary

1. *Repetition of Katzaroff's experiments.*—As a preliminary to our investigation, we undertook to repeat the work of Katzaroff. Our method was an exact duplicate of his; but we employed only thirty-six of his seventy-two drawings. Our experiment, therefore, while less extensive than his, was identical with it in the details of each sitting. Our observers included four men and four women, all of whom had had laboratory training in psychology; two were special students, and three were instructors in the department of experimental psychology.

Eighteen drawings were presented at each sitting, in groups of six, each drawing being exposed in a tachistoscope for six seconds, with an interval of four seconds between exposures. An interval of five minutes elapsed after the first and again after the second group of six. The observer was instructed to note each design carefully in order that he might be able to identify it later. He was told that after the series had been exposed, he would be shown these same drawings again, together with eighteen other very similar drawings, distributed irregularly among them. His task was to consist in determining whether the drawing presented in this subsequent series was identical with one seen in the first series, whether it was similar but not identical, or whether it was wholly new; and he was asked to distinguish four degrees of certainty of judgment,—absolutely sure, fairly sure, sure, and doubtful. Immediately after his judgment of each drawing of the recognition series, he dictated a detailed introspection to a stenographer, who was screened from view. The results of these experiments corroborated Katzaroff's findings in certain particulars, but they contradicted Katzaroff's findings in other particulars.

First, as to the rôle of the image in the act of recognizing: Katzaroff is convinced that imagery is not essential; he maintains that recognition has two distinct stages: first, the appearance of a feeling of familiarity; second, the appearance of images and memories. And he finds that the first of these is the initial process in every act of recognizing, while the imagery functions merely in a corroborative fashion. In an overwhelming majority of cases, our observers analyzed their recognitive consciousness into imagery and kinaesthesis, with occasional affective toning. However, cases in which a feeling of familiarity or of strangeness seemed immediate and unanalyzable were reported in a few instances by our observers. These unanalyzed

attitudes occurred most frequently in those cases where, as a variant of Katzaroff's procedure, we gave our observers a repetition of the same series at a later date. This finding suggested that the function of imagery may now have become less prominent because the material had become more familiar; and we made use of this suggestion in planning our next series of experiments.

Second, Katzaroff finds that the time required for making a judgment regarding designs which had already been presented but which had been forgotten, is greater than that required for similar designs which had not previously been seen; and he finds in this phenomenon a warrant for assuming that subconscious processes are in action here,—the material not being wholly strange in the former case. We have failed to confirm this difference in time; and we can see no justification for Katzaroff's appeal to that convenient hypothesis, the subconscious.

Third, in one other respect our results seem to warrant a rejection of Katzaroff's conclusions. He finds that recognition is essentially an affective process, and he believes that it is always enveloped in a consciousness of self. Our introspections fail to confirm this finding; in many instances, no trace of affection is to be found, and consciousness of self appears still more rarely.

In brief, we corroborated Katzaroff's findings in the following particulars: *a.* Imagery is lacking in many introspective descriptions of recognition; but we are not prepared to assert that imagery is never, or even that it is seldom essential to the recognitive consciousness. These preliminary experiments indicated that this consciousness has several, perhaps multitudinous stages, and that imagery plays a somewhat different rôle in each. *b.* The act of recognizing is frequently characterized by a conscious comparison of image and percept; this is especially true of the recognition of relatively novel objects. *c.* There is no correlation between subjective certainty and objective correctness.

We failed to corroborate Katzaroff's findings in the following particulars: *a.* The initial stage of every act of recognizing consists in the appearance of a 'feeling of familiarity'; and imagery serves only the secondary function of confirming or correcting this primary act of immediate recognition. *b.* Recognition is always an affective rather than an intellectual process, and it inevitably involves a consciousness of self.

2. *Preliminary experiments with photographs of persons and places, advertisements, block letters, different faces of types.*—For a second series of preliminary experiments we selected materials which, we hoped, our observers would find to possess widely different degrees of familiarity. We secured postcard views from the home cities, colleges, etc., of each of our eight observers, and among these familiar pictures we distributed views of Worcester, of Clark University, and others more or less familiar or wholly unknown; we also employed a series of Perry pictures of prominent men and women, and a group of more or less familiar advertisements. The eight observers who served on the previous problem served in these experiments also. Two methods of visual presentation were employed: First, the picture was either seen through an aperture giving a rapidly recurring series of instantaneous exposures in a rotating disc, or it was exposed by means of a mechanism which provided a continuous exposure but at a variable distance from the observer. The arrangement was

such that the picture could be presented at a distance where its details were imperceptible; then, while the picture was brought progressively nearer and nearer to the observer's eye, in continuous exposure, the details gradually emerged and became clear. The object in both these methods of presentation was to build up a process of recognition by gradual increments, so that the observer might be enabled to examine and give an account of its genesis and development.

Another series was designed to analyze the act of recognizing a tactual stimulus. Here we employed wooden blocks upon whose faces were cut letters of the alphabet, and digits, averaging eight centimeters in height; this series also included various objects such as a watch, a pipette, a small bronze medal, etc. The observer was blindfolded and the object to be recognized was placed in his hand. He immediately dictated a report of what went on in consciousness. If he failed to recognize the object he explored it still further, and then gave an account of the mental processes involved in his final attempt to identify it.

Data in all four of these series indicated that imagery played a very important rôle, and that it was supplemented by organic sensations and kinaesthesis. Imagery was the first and only content reported in the majority of cases. Affective toning was rarely reported, as also was consciousness of self. It was found that the observers usually adopted a procedure which consisted in reconstructing the situation in which the stimulus-object had formerly or usually been experienced in everyday life; this act of reconstructive recognition was usually characterized by a mass of imagery, sometimes detailed but often sketchy, in which the visual and the motor modalities predominated.

The results of these experiments indicate that imagery is of extremely variable significance in the act of recognizing. In certain instances, our observers reported a profusion of images which were vivid and rich in detail; in other instances their imagery was scant, indefinite, and schematic. Numerous introspections indicate that an inverse relationship obtains between abundance and richness of imagery on the one hand, and facility of recognizing on the other hand. In cases where the object or picture was relatively unfamiliar, and where the act of recognizing it was hesitant and difficult, the imagery was abundant and rich in detail. The discovery of this state of affairs suggested a method which promised to furnish a more detailed analysis of the recognitive consciousness, and a clearer insight into the component processes which contribute to the act of recognizing. And in all of our subsequent experiments we adopted a procedure which consisted in presenting materials which were unfamiliar at the outset, and in re-presenting them at intervals until they were recognized without difficulty. It was hoped that the introspective reports of these successive acts of recognizing stimuli, which must of necessity grow more and more familiar, would constitute essentially a series of cross-sections through the recognitive consciousness at successive points between its initial, hesitant stage, and its final, facile and mechanized stage.

In a final series of preliminary experiments, the materials chosen were alphabets printed from five different faces of type, each representing a characteristic variant from the common letter-form. These variant letter-forms were wholly unfamiliar to the observers at the outset; and the experiment consisted in having him describe the mental contents and the mental procedures employed in successive

acts of recognition at various stages throughout the process of learning. The lower-case alphabets were arranged in vertical columns, side by side, on a strip of white paper 6 cm. wide. This strip was placed on the drum of a Spindler and Hoyer exposure-apparatus, and the mechanism timed to furnish a three-seconds' exposure. The name of each face of type was plainly printed on the bevel of the exposure aperture, so that it would appear just below the column to which it belonged.

Six observers took part in this experiment. All had had training in introspection, and four of the six were specially trained students and investigators in experimental psychology. The experiments were begun April 3, 1912, and concluded June 6, 1912.

The observer was instructed to note the letters as they appeared (the row of five different "a's," then the "b's," etc.), in any fashion he chose, endeavoring to learn the characteristics of the different faces. After the exposure of the entire series, the observer was shown isolated letters from the list; he was asked to name the type to which each isolated letter belonged, and then to give a detailed description of the processes involved in his recognition, or attempted recognition. The observer was given his own time in the test series, the experimenter noting by means of a stop-watch the number of seconds required in each case. The sittings usually required from thirty minutes to an hour, though rarely the latter, so the element of fatigue was a negligible factor; the sittings were continued until the observer succeeded in recognizing immediately the 'face' to which each letter belonged.

The significant fact shown by these experiments is the marked decrease in the amount, variety, and clearness of imagery present in the recognitions as the letter-forms became more and more familiar to the observer. Many other points of interest appear in the results of these experiments,—some confirming beliefs widely held, some contradicting the results of other investigators in this field. Our data show that: *1.* The time required for the act of recognizing decreases as the object becomes more familiar; *2.* the degree of subjective certainty and the proportion of correct recognitions increase as the object becomes more familiar; *3.* affective toning is wholly absent in the great majority of recognitive experiences; *4.* no consciousness of self is present in the act of recognizing save in rare and exceptional instances; *5.* the 'feeling of familiarity' rarely, if ever, appears as an unanalyzable and *sui generis* experience; *6.* experiences of a motor sort become more and more dominant in proportion as the act of recognizing becomes more facile and more certain.

As the data accumulated, we discovered a serious defect in our method of presenting this series. By arranging all five alphabets side by side and exposing the letters in rows (all the "a's" in one row, all the "b's" in the next, etc.), we had put a premium on the spatial localization factor of memory; and our introspections showed that our observers tended to identify any given letter by referring it directly to the position in the row (first, second, third, fourth or fifth) which it had occupied during the exposure of the series. We believed this might account for the predominance of kinaesthesis in the recognitions of our observers (eye-movements, imaged or innervated, having been frequently reported), as well as for visual schemas which were common. We corrected this defect of method in the visual series of the final experiments.

B. FINAL EXPERIMENTS

A. The preliminary experiments had shown that there is great diversity in the mental experiences which are known by the name of recognition. They had made it clear that it is not sufficient to mark off two great types of this process and to call *immediate* or *direct* that recognition which follows immediately upon perception,—where a given stimulus seems familiar the moment it is perceived, with apparently no intervening process whatever,—and *mediate* or *indirect*, that recognition in which associations appear in consciousness before or simultaneously with the consciousness of familiarity. Our introspective accounts had indicated not only that extreme cases of incipient and complete familiarity are characterized by more marked differences in the contents of consciousness than has usually been supposed, but also that there are several, perhaps many, intermediate stages between these two extremes.

We undertook to investigate these intermediate stages, as well as the two extremes; and in order to have a means of measuring and comparing them in the course of their development we devised a genetic method. We chose materials which were novel and taught them to our observers, taking an introspective cross-section of the recognitive consciousness at numerous levels between the initial and the mechanized stages.[3] The problem was attacked in four sense departments,—visual, auditory, tactual, and olfactory.

A. *Method and Material Employed in Experiments in the Recognition of Visual Stimuli.*

The materials chosen for this experiment were five different faces of type,—Della Robbia, Bulfinch, American Typewriter, Clearface, and DeVinne. The capital letters of a given face were arranged vertically, in alphabetical order, on a band of paper designed for exposure on the drum of a Spindler and Hoyer exposure apparatus,—a device which gives a series of exposures, each of which is made during a pause in the movement of the revolving drum. The printed name of the type was placed just above the exposure apparatus. The exposure-time allowed to each letter was four-tenths of a second. The observer was seated before the apparatus, and was told that he was to observe the letters with the purpose of being able, eventually, to recognize any one of them as belonging to a particular face of type. He was told, further, that he was not to feel constrained to learn these types at one, two or half a dozen sittings; he was made to understand that the experimenter was not interested in the quantitative results, but rather in the introspective accounts of what goes on in mind when a given visual stimulus is recognized as familiar. The name of the type was pronounced to the observer, then the 'ready' signal given, the apparatus set in motion, and the shutter

[3] We shall use the term 'initial recognitions' to designate the first or earliest of our observers' identifications of the material learned,—those recognitions in which there was usually only a slight degree of familiarity. The name 'final recognitions' will be given to those later experiences in which the observers' familiarity with the stimuli was complete, but in which it was still a conscious content. This study is not concerned with mechanized experiences which are practically reflex reactions to stimuli, and in which no consciousness of familiarity is present.

opened. The entire alphabet was displayed from beginning to end. At the close of the exposure, the observer gave an introspective account of his procedure, which was taken down by a stenographer. In this manner, all five of the faces of type were displayed in turn, but in different order, at each sitting.

At the beginning of the second and of each subsequent sitting, tests were made of the observer's familiarity with the types in the following manner. Single letters of the various types, printed on cards, were exposed in exactly the same position as that occupied by the letters in the learning series. The observer was asked to report, as soon as he could, whether or not he recognized the face to which the letter belonged, and to give an account of everything which was present to consciousness from his perception of the stimulus until his recognition was reported, the time required for the recognition being recorded by means of a stop-watch. The observations were made once each week, from March 3, 1913, to May 12, 1913.

Four observers served in this experiment, all students or instructors in the department of psychology in the University. They were: *F.*, instructor in the department of experimental psychology; *Fn.*, laboratory assistant and fourth year graduate student in experimental psychology; *Fs.*, fourth year graduate student in experimental psychology; *W.*, first year graduate student in experimental psychology. The observers did not discuss the problem either with each other, or with the experimenter.

B. *Method and Materials Employed in Experiments in the Recognition of Auditory Stimuli*

The material chosen for this part of the experiment comprised various airs and themes from operas, symphonies, songs, etc. Care was taken to select for each observer only such compositions as were entirely unfamiliar to him when the experiment began. The following is a list of the selections employed, either as a whole or in part: *Tschaikowsky,* Danse Trepak, Overture 1812, Song without Words, Sleeping Beauty Ballet, Fifth Symphony; *Reissiger,* Yelva Overture; *Humperdinck,* Hansel and Gretel; *Verdi,* Rigoletto, Il Trovatore and La Traviata; *Leybach,* Fifth Nocturne; *Tobani,* Songe d'Automne, Hungarian Fantasia; *Goldmark,* Brautlied. The selections chosen were all orchestral, in order that, so far as possible, the recognitions should have to do with the air alone.

The music was played on a Victor Talking Machine, placed in a box in a room adjoining the experimenting room. The sound was conveyed to the observers' ears through the wall by means of a rubber tube which terminated in a pair of stethoscopic ear-tubes. A stop-cock in the tube, between the phonograph and the wall, enabled the experimenter to control the part and amount of the selection which was presented to the observer.

The observer sat in a comfortable chair, having on its right side a broad arm to which was screwed a reaction-key communicating with another key placed on the phonograph box. He was instructed to give one tap on the reaction-key when the music became familiar, and two or more taps when he could identify the selection. When this latter signal was given, the music was instantly shut off; and the experimenter recorded the observer's introspective report of his mental processes from his perception of the ready signal to the appearance of his recognition of the selection.

At the first sitting, from three to seven airs were presented to the observer, the name of each being given him in both visual and auditory fashion. At the close of the selection, the observer gave a detailed account of his procedure throughout. This was done after each act of learning as well as after each test of recognition. At later sittings, besides a new air or two, the selections already played to the observer were given him again and if he failed to recognize them, the experimenter named them and played them through once more. The time required for each recognition was recorded by means of a stop-watch. Occasionally an entirely new air was played and this check brought out some very interesting experiences of non-recognition which will be discussed later.

This series of experiments was begun in November, 1912, and continued with each observer until the recognition of most of the selections had become immediate. The last sitting took place February 19, 1913. Six observers took part in these experiments,—all students or instructors in the psychological department of the University. They were *F.*, *Fs.*, *W.*, and *Fn.*, who assisted in the visual series already described, and *V.* and *B.*, third year graduate students in psychology.

C. *Method and Material Employed in Experiments in the Recognition of Tactual Stimuli*

The method employed in this series of experiments was essentially the same as that used in the visual and auditory series. Our observers were taught to recognize tactual stimuli which had been wholly novel and unfamiliar at the outset; and introspective cross-sections were taken throughout the course of the mechanization of their acts of recognizing these stimuli.

The materials employed were the letters of the alphabet for the blind (New York Point). In the learning series, the blindfolded observer sat in the ordinary writing position, with his right arm resting upon a frame within which the letters were presented. He was instructed to explore with his finger-tip each tactual stimulus which would be presented, and to learn to recognize these stimuli when they should subsequently be given to him. A sheet containing a single letter was then placed in the frame; and at a given signal, the observer began his exploration, the experimenter pronouncing the name of the letter. Thirty seconds were allowed for each exploration in the learning series; and the observer gave an introspective account of his procedure at the expiration of that time. Not more than five new letters were presented at a single sitting.

In the recognition series, the observer was asked to explore the stimulus and to report whether or not it was familiar; in the case of a familiar stimulus, he was instructed to recall the name if possible. The time required for the act of recognition was noted in each case, and a stenographer recorded the observer's introspective report of his procedure. When he failed to recognize a letter, or when he made a false recognition, he was asked to explore the same stimulus again and the correct name was supplied by the experimenter. This procedure was continued until the recognitions were made without hesitation. Five of our observers: *F.*, *Fn.*, *Fs.*, *V.*, and *W.* took part in this series of experiments. The observations began October 31, 1912, and closed February 24, 1913.

D. *Method and Materials Employed in Experiments in the Recognition of Olfactory Stimuli*

In a fourth series of experiments, observers were taught to recognize a number of different odors, including: (1) Novel perfumes,—Quelques Fleurs, Acme Violet, Coast Violet, Trêfle, Halcyon Rose, Sous Bois, Bouquet Janice, Bruyère Rève, and Flowers of Savoy; (2) a series of alcohols,—Ethyl, Methyl, Amyl and Butyl; several coal tar products,—Cresol, Phenol. Other odors were often used as controls.

These substances were kept in bottles of uniform size, and they were handed to the blindfolded observer, who removed the stopper and sniffed the odor in the manner that seemed most natural and convenient to him. In the learning series, which never exceeded eight in number, he was told the name of the odor, and allowed to investigate the smell quality as long as he wished. As he dictated an introspective account after each experience, the olfactory membrane had ample time to recover between stimulations. The interim always exceeded the time found by Zwaardemaker[4] to be necessary for recovery from complete fatigue of the membrane,—a condition which occurred in one case only during the entire experiment.

In the test series, the observer was given various of the bottles, one at time, and asked to identify each odor if he could. He was allowed to signify his recognition by handing back the bottle, giving the odor's name, or in any way that he chose. In each experience, the time consumed from the presentation of the stimulus (the actual sniffing of the odor) to the observer's reaction signal was recorded and his introspection was taken down by a stenographer.

Seven observers took part in this experiment: *F., Fs., W., V., S., O.,* and *Bd.* The last three served only in the olfactory series. *O.* and *S.* were graduate students in psychology, *Bd.* is Professor of Psychology and head of the Department of Experimental Psychology.

2. RESULTS

A. *Introspections.*—In this section we present typical introspections obtained from each observer in each series of these experiments.

Observer F.

Introspections on the Recognizing of Visual Stimuli

1.[5] April 2, 1913. Clearface 'A,' 10 sec. (8th. presentation; first correct recognition.) "As soon as I saw the letter I was conscious of a vocal-motor image 'big, thick,—what *is* that thing?' There was a decided bodily strain, rather widely diffused; I repeated 'big, thick,' over and over, in vocal-motor imagery, until suddenly 'big, thick Clearface' rushed into consciousness in vocal-motor and auditory terms, the accent on the 'Clearface' expressing my annoyance at being so slow. I tapped the key at that point."

2. April 16, 1913. Clearface 'A,' 7 sec. (9th. presentation.) "On perceiving the stimulus I found myself repeating 'big, thick' in vocal-motor auditory imagery. It was very familiar. I went through the

[4] H. Zwaardemaker, *Die Physiologie des Geruchs.* Leipzig, 1895.

[5] The serial number at the beginning of the introspection, to the left of the date, is a purely arbitrary number which is inserted here for convenience in subsequent reference.

list of types in this manner, in vocal-motor auditory imagery: 'big, thick Della Robbia; big, thick De Vinne; big, thick American Typewriter; big, thick Clearface.' Then I repeated this last phrase quickly and with assurance. There was increasing tension throughout these processes, with relaxation of strain at the last, as soon as I tapped the key."

3. April 24, 1913. Clearface 'A,' 1 sec. (10th, presentation.) "As I became aware of the visual stimulus, I had, in vocal-motor auditory imagery, 'big, thick Clearface,' with relaxation of tension and absolute surety."

4. April 30, 1913. Clearface 'A,' 6 sec. (11th. and last presentation.) "On perceiving the letter I was conscious of immediately tapping and saying 'Clearface.'"

The Recognizing of Auditory Stimuli

5. Dec. 10, 1912. 'Overture 1812,' 10 sec. (1st. recognition.) "This air seemed slightly familiar almost from the first. My consciousness was entirely filled with vocal-motor and auditory images of the air, which anticipated the tones that were being played. There was a slight tension throughout my whole body. When the 'Russian National Hymn' came, the words 'Hail, Pennsylvania' appeared in vocal-motor imagery, with some innervation. Then vocal-motor '1812' followed in consciousness, and I promptly reacted on the key. Tension relaxed when the '1812' image appeared.

6. Jan. 16, 1913. 'Overture 1812,' 3.6 sec. (2nd recognition.) "The first thing of which I was conscious after the music began was the vocal-motor imagery 'I know that.' There was tension in forehead and eyes, but no images of humming. Then '1812' suddenly appeared in consciousness in vocal-motor imagery; tension relaxed and I found myself reacting."

7. Jan. 29, 1913. 'Overture 1812,' 1.4 sec. (3rd. recognition.) "Vocal-motor and auditory imagery of the word 'Hail,' sung in my own voice, and prompt reaction on the key, with relaxation following. The name of the selection came immediately afterwards, but was not a part of my consciousness of familiarity."

8. Jan. 29, 1913.[6] 'Il Trovatore' (Verdi), 3.8 sec. (5th. recognition.) "Vocal-motor imagery of humming the air, anticipating the music after the second note. Then in rapid succession came the vocal-motor images 'Verdi group; Trovatore.' Slight muscular tension at first, diffused over the body, which relaxed at the word 'Trovatore.'"

9. Jan. 29, 1913. 'Brautlied' (Goldmark), 2 sec. (7th. recognition.) "Keen attention to auditory stimulus at first with nothing in consciousness but the auditory perception. With the fourth note,—that sliding one,—distinct vocal-motor imagery of singing that sliding note myself, followed by vocal-motor 'Goldmark's Bridal March,' and instant relief."

The Recognizing of Tactual Stimuli

10. Nov. 27, 1912. 'a' (Two dots in a horizontal line.) 7 sec. (4th. presentation; 1st. recognition.) "When I got this stimulus in

[6] In addition to the progressive series of introspections, we have included here certain other introspections which illustrate points to be discussed later.

tactual terms I was aware of an auditory and vocal-motor image of 'a,' with a questioning accent. I had no high degree of certainty, however; and I inhibited my reaction and explored the stimulus further. A visual image of three dots arranged in a horizontal line came to consciousness, and with it a vocal-motor auditory 'f.' Then I was aware of a series of auditory vocal-motor images somewhat as follows: "'a' used oftener, simple, 'a,'" meaning that 'a' occurs more frequently than 'f' in actual use and therefore the simpler form of two dots would be employed to represent it. This, then, is 'a.' There was a diffuse bodily strain throughout until this last process, with relaxation at the end."

11. Dec. 12, 1912. 'a,' 2 sec. (6th. presentation.[7] "As soon as I got the tactual perception I had a vocal-motor auditory image of 'two dots.' Then I was aware of a tactual image of two dots, and a kinaesthetic image of reaching toward the right; 'a' followed immediately in vocal-motor auditory imagery."

12. Jan. 20, 1913. 'a,' 1.4 sec. (8th. presentation.) "I had a kinaesthetic and tactual impression of two dots in a horizontal position; and immediately afterwards a vocal-motor auditory image "two dots, 'a.'"

13. Feb. 6, 1913. 'a,' .8 sec. (9th. presentation.) "A vocal-motor auditory image of 'a' came to consciousness immediately with my awareness of the number of dots in tactual terms, and of their horizontal position in kinaesthetic terms. Then I was aware of turning from the problem with instant relief."

The Recognizing of Olfactory Stimuli

14. Jan. 24, 1914. Ethyl Alcohol, 20 sec. (3rd, presentation; 1st. recognition.) "I sniffed it; and 'alcohol' came to consciousness in vocal-motor imagery. I was distinctly aware of the cooling sensation in my nose. It seemed familiar but no name came to me, and I was aware of unpleasantness, and the words Which one? Don't know. I'll never get them.' I kept on smelling, but the unpleasantness increased, and a general feeling of despair took hold of me,—a sinking organic sensation, which seemed somehow to include my whole body."

15. Jan. 31, 1914. Ethyl Alcohol, 17 sec. (4th. presentation.) "On perceiving the coolness which my first sniff of this produced in my nose, I said, 'Alcohol.' This was in vocal-motor imagery, with a rising accent. Then I smiled and said, 'Yes, alcohol. Let's see,—Ethyl or Methyl or Butyl?' Then I was aware of getting a drop of it on my nose and immediately had, in vocal-motor imagery, 'Now, I'll cough!' There was then a perceptible moment of waiting for that cough, and when it failed to appear, the Butyl possibility slipped out of consciousness altogether, and I said 'Methyl or Ethyl, not sure which.'"

16. Feb. 14, 1914. Ethyl Alcohol, 14 sec. (5th. presentation.) "I approached it with a definite perfume-*Einstellung*. I was saying to myself, 'They alternate, perfume,—alcohol—benzine group—perfume.' I took several whiffs before I could decide whether it was alcohol or perfume. This was present in terms of vocal-motor imagery of

[7] It sometimes happened that successive introspections in a series were practically identical with one another. These duplicate introspections have not been included here,—the omission being indicated by a discontinuity in the serial numbers of (presentations or) recognitions.

this sort: 'Not perfume, alcohol; no, perfume; no, alcohol,' etc.; finally, '*mild* alcohol.' Then I was aware of the coolness in my nose and attention was focused on this. The odor began to seem definitely familiar and I said 'cool in nose, mild alcohol, Ethyl.' My signal-tap ushered in distinct relaxation."

17. Feb. 21, 1914. Ethyl Alcohol. 9 sec. (6th. presentation.) "I was aware of the quality of the odor and then of vocal-motor 'alcohol? Not Butyl or Amyl; what—Ethyl, Methyl? Oh! cool in nose, Ethyl.' Then I turned to you, pleased with my success."

18. March 28, 1914. Ethyl Alcohol, 1 sec. (7th. presentation.) "Immediate vocal-motor 'alcohol—cool, Ethyl.' A high degree of certainty as I tapped."

Observer Fn.

The Recognizing of Visual Stimuli

19. April 21, 1913. Bulfinch 'E,' 8 sec. (5th. presentation; first correct recognition.) "The perception came in slowly and aroused a memory experience of myself going through this experiment at a former sitting. There was visual imagery of the room and the apparatus, and kinaesthetic and organic images of myself experiencing it all. Then followed imagery of a sitting previous to that in which I had noted this letter in the Bulfinch series. Two places in my visual schema claimed my attention here, and although there had been consciousness of familiarity throughout, it gradually increased in intensity until the names of those two places came in vocal-motor imagery: 'old Clearface,—Bulfinch.' The latter name was stressed and with its appearance the Bulfinch place in my schema[8] became focal in consciousness."

20. April 28, 1913. Bulfinch 'E,' 1 sec. (6th. presentation.) "My perception of that letter thrilled me all over,—I was especially conscious of sensations of thrills in my chest. I localized this type in my schema, and the schema in my experience of last week; it was sufficient to make me absolutely certain. I said 'all right'; and it was not until after that that the name 'Bulfinch' appeared in vocal-motor imagery."

21. May 5, 1913. Bulfinch 'E,' .4 sec. (7th. presentation.) "The perception itself bore an intensive consciousness of familiarity, which seems to consist in its ease and readiness; the experience culminated in the instantaneous relaxation of the initial tension, as the Bulfinch part of my schema flooded into consciousness."

The Recognizing of Auditory Stimuli

22. Jan. 11, 1913. 'Brautlied' (Goldmark), 10 sec. (5th. presentation; first recognition.) "Four or five notes had gone before I realized that I was familiar with the air. My familiarity seemed to consist in the facility of my perception of the tones. I found myself turning back to repeat the first part in auditory imagery. My visual schema for the Tschaikowsky group came to consciousness vaguely,—indeed, it was so dim that I was not conscious that it was my Tschaikowsky schema until afterwards. It was merely a dim visual image of five gray blotches, and this air did not seem to fit into it,—no definite associations with this air occurred and the schema dis-

[8] For description of this schema, see p. 351.

appeared from consciousness. Then I visualized a long note, on a music score, with four short notes straggling down from it, and then four others ascending the scale again." (This was *Fn.'s* schema for the 'Yelva Overture.') "My auditory imagery would not fit into that schema, either, so that possibility was discarded. Suddenly, with no discoverable antecedent, 'Natoma' occurred to me in vocal-motor and auditory imagery, and I was conscious of innervation in my reacting arm; but the reaction was inhibited by a new process,—I actually turned around and looked over across the table where, for some reason, I have always located 'Brautlied.' My whole attitude of body and mind was a questioning one. Then I turned back satisfied, tension relaxed, and I found my hand pressing the key. I was not aware of the name 'Brautlied' until afterward."

23. Jan. 27, 1913. 'Brautlied,' 5 sec. (2nd. recognition.) "Intense excitement. Familiarity just stirred my whole body. The whole situation in which I last heard this selection came up in visual imagery. Then 'Tschaikowsky' appeared in auditory imagery, but my attention turned from this immediately; and 'Brautlied' in auditory imagery, together with a humming of the air, filled my consciousness and I reacted."

24. March 3, 1913. 'Brautlied,' 1 sec. (3rd. recognition.) "The very first note had a perfectly definite familiarity,—simply thrilled me all over. That familiarity seems to be the sum total of my bodily reactions to the music. The name 'Brautlied' did not occur until a moment later, when it appeared in vocal-motor and auditory imagery."

The Recognizing of Tactual Stimuli

25. Nov. 23, 1912. 'e' (A single dot.) 16 sec. (2nd. presentation; 1st. recognition.) "As soon as I got a tactual impression of a single dot, I recalled the past situation here, in an endeavor to remember if any letter which had been presented had consisted of but a single dot. There was no familiarity in the actual experience, and I felt sure that the experimenter would never have given me so simple a figure. I attended keenly to the stimulus, and to both the visual and tactual imagery of other letters which had formerly been presented; 'g,' 'f' and 'h' stood out clearly. Then 'e' came to consciousness in auditory imagery of the experimenter's voice. Still no familiarity appeared. Then I had a tactual image of one dot, together with a visual image of a letter 'e'; I was not sure whether these were images of memory or of imagination. Still my image of the letter 'e' took its place in a visual schema which was then referred to the first day's experience and I reacted."

26. Dec. 14, 1912. 'e,' 5 sec. (4th. presentation.) "The tactual sensations called up a memory of the whole situation in which this stimulus was last presented,—not in visual imagery alone. The experience is rather that of living over again the former experience with its tactual imagery of this single dot, and auditory imagery of my own voice calling it 'e.'"

27. Dec. 21, 1912. 'e,' 2 sec. (5th. presentation.) "I perceived a single dot immediately, but my attention was directed to an attempt to find more than one. I was conscious of exploring rapidly all around this dot several times. Then the 'e'-ness of that single dot became focal and had a sort of familiarity which seems to consist simply in my tendency to attend to it, though my finger was still

exploring for others. About this time, I called this stimulus 'e,' pronouncing the name aloud."

28. Feb. 15, 1913. 'e,' .4 sec. (8th. presentation.) "I had no more than touched the stimulus when a perception of the singleness of the dot came to consciousness. There was a visual image of the one dot, and just an immediate flash of familiarity which seemed to consist in the way the sensation attacked me,—the rapidity with which it came to consciousness, and the permanence of its quality. I was conscious of a motor response to it,—a sort of diffuse bodily thrill, faint, yet distinct. There is always something of this bodily thrill in my recognitions."

Observer Fs.

The Recognizing of Visual Stimuli

29. March 11, 1913. Clearface 'E,' 2.6 sec. (2nd. presentation; 1st. recognition.) "I examined this letter very carefully, noting the serifs and the hair lines; my attention seeming to turn naturally from one feature to another. My visual schema came into consciousness; and this letter located itself toward the last of the five blotches of the schema,[9] one of which seemed to be more clearly defined. I was conscious of a mental effort to name all the blotches. The second from the top I called 'Bulfinch,' in vocal-motor imagery; then I named the one above it 'American Typewriter.' There was tension then, and a period of suspended action before I corrected this by calling the first 'Della Robbia' and the middle one 'American Typewriter.' Then my attention turned to the last two, vacillating between them for a time; but finally I paused for a perceptible interval on the very last. At the same time the name 'Clearface' came to consciousness in vocal-motor imagery and I reacted. There is no high degree of surety even now."

30. March 17, 1913. Clearface 'E,' 1.6 sec. (2nd. recognition.) "The first thing I noted was the general size and heaviness of the letter, and the difference in the widths of its lines. All of this was present in my visual perception of it. Then I had, almost immediately, a visual image of 'Clearface,' the word beginning with this particular 'C.' This was localized at the end of my visual schema, the rest of it being barely present to consciousness. I was not aware of any affective toning. I immediately tapped on getting my visual cue."

31. April 3, 1913. Clearface 'E,' 1 sec. (3rd. recognition.) "I perceived that the letter was large and had clearly marked differences in width of line. There was an immediate tendency to set my mouth for saying 'Clear——,' chiefly imaginal, I think. My attention was increasing all the while and my uncertainty decreasing. Finally, I said 'Clearface' and attention shifted immediately. There was scarcely any awareness of familiarity this time."

32. April 17, 1913. Clearface 'E,' .4 sec. (4th, recognition.) (The observer had been instructed, this time, not to react, nor to try to recognize, but simply to observe the stimulus-letter, and later to tell her experience.) "I was aware of an attention to the letter, of noting the widths of its lines together with its size and general boldness. The word 'Clearface' rushed into mind instantly, the syllable 'Clear' in vocal-motor, and 'face' in auditory imagery."

[9] For a description of this schema, see pp. 354 f.

33. May 12, 1913. American Typewriter 'O,' .6 sec. (12th. recognition.) "I was immediately aware of the size and narrowness of the letter. My recognition of it was instantaneous and consisted in a tendency to react, *i. e.*, an awareness of tension in my right hand and about the muscles of my chest, as though I were holding my breath. The name appeared an instant later, in vocal-motor imagery, in very much abbreviated form: 'Am. Tyr.'

The Recognizing of Auditory Stimuli

34. Nov. 21, 1912. 'Natoma' (Victor Herbert), 10 sec. (2nd. presentation; 1st. recognition.) "With the first phrase of the music, I experienced a sudden kinaesthetic relaxation and a forward movement as though to get nearer the source of the sound. 'Dream of Autumn' came to consciousness in auditory vocal-motor imagery; then 'Tales from Hoffmann.' I had a strong tendency to react; I was aware of tension in my right arm. My foot was tapping, too. Suddenly that measure which contains the drum beats claimed my attention, and 'Natoma' rushed into consciousness in vocal-motor imagery. That process was accompanied by a forward movement of my whole body,—a thrill all over,—and then I reacted."

35. Dec. 2, 1912. 'Natoma,' 8 sec. (3rd. recognition.) "There was a slight consciousness of familiarity from the first. I paid close attention to the music and followed the rhythm slightly with bodily movements. I thought it was from some opera,—the word 'opera' being present in auditory vocal-motor imagery and after it 'Carmen.' (That merely by way of association.) This possibility was immediately discarded,—just slipped out of mind. Then I was aware of tension,—of a slight forward movement, and 'Natoma,—why, of course, Natoma,' came to consciousness in vocal-motor auditory imagery."

36. Jan. 16, 1913. 'Natoma,' 5 sec. (5th. recognition.) "At first I was keenly aware of the two chords and their minor quality. The air had a definite familiarity. There was slight tension, rather diffuse, and 'Natoma' appeared in vocal-motor imagery. With that I had a tendency to react,—this in terms of a vague awareness of kinaethesis in my reacting arm. The reaction was inhibited by a recollection of having confused 'Natoma' with 'Dream of Autumn' before,—this being present to consciousness in terms of a visual image of two names printed one after the other, and some visual imagery of this room and of the situation at a former sitting. My certainty that this was 'Natoma' increased. The air went on and finally the 'Dream of Autumn' faded out of my imagery and I reacted."

37. Jan. 28, 1913. 'Natoma,' 3 sec. (7th. recognition.) "I fell into the rhythm immediately; felt my head and shoulders swaying with it, and started to react. It was perfectly familiar. Then the word 'Natoma' occurred in vocal-motor imagery and I gave the signal."

38. Jan. 16, 1913. 'Danse Trepak,' 7 sec. (7th. presentation; fourth recognition.) "With the first note there was perfect awareness of familiarity with the music. Could not react rapidly enough. The consciousness of familiarity was made up of two components: a rapid impulse toward the reaction-key, and a visual image which seems to be a product of that old image of the disc containing five selections, but this time it appeared as five very gray blotches which might be manuscript music. The upper blotches seemed clearer, and attention

was directed toward them. I wanted to give the signal because I was well aware that I knew the name of that air, but the reaction was inhibited. This is my interpretation of my awareness of strain in my poised, reacting hand."

39. Jan. 28, 1913. 'Danse Trepak,' 1.4 sec. (9th. presentation.) "On getting the first auditory sensation I immediately started following it out in vocal-motor and auditory imagery of humming and gave two taps, automatically. The absolute automatic perfection with which I fell into that music just seemed to be accompanied by the two taps. *Afterwards* I started to recall the name, getting a visual image of a phonograph disc, larger than the usual full-sized discs, and having five distinct divisions in its threads, marked by deeper grooves.[10] My attention was directed to the first of these divisions, coincident with vocal-motor image of 'what' which meant: 'What was the name of that?'"

40. Dec. 2, 1912. 'Traviata.' (1st. presentation.) "There was no familiarity throughout the whole experience. The rapidity of the music first brought up a visual image of the disc with the five airs on it. This was non-focal, attention all the way through being on the music. The first tempo was very pleasing. I noticed that the trills were being played differently. The word 'new' in vocal-motor and auditory imagery was present with a decided inflection. There was intense kinaesthesis in the feet and hands, and I even went so far as to press the key automatically. My whole body seemed to swing; but no name occurred, nor was I aware of any search for one."

The Recognizing of Tactual Stimuli

41. Jan. 27, 1913. 'f' (The 'f' is represented by three dots in a horizontal line.) 10 sec. (5th. presentation; 1st. recognition.) "Just as soon as I became aware that the dots of the stimulus were in a straight line, the word 'what' came to consciousness, in a setting of the vocal-motor apparatus for saying 'what?' With this I had visual images of several different arrangements of dots which seemed to represent experiences similar to this in the past. A visual image of the letter 'a' appeared also, and all of this went to make up my attitude of 'What letter is this?' rather than 'Have I seen it before?' This attitude seemed to initiate my consciousness of familiarity with the stimulus. I then re-explored the group of dots to find the exact number of dots; and when I perceived that there were three, this attitude became still more intensive. I remembered that I had had this group of dots before, the remembrance consisting in a visual image of a card having three dots on it, together with bits of imagery of this room and the general situation. My 'what-is-it?' attitude persists, but I can not name this letter." (At this point in the introspection, the name of the letter was told to the observer.) "Now I remember; and the recall came in motor fashion. When I was learn-

[10] The reference to a visual image is an experience which *Fs.* frequently described in connection with the five different Tschaikowsky selections, all of which were on the same disc. Danse Trepak was the first in order. In the initial learning the entire record was played through, a list of the names of the airs having been given the observer. This image ran a most interesting course in consciousness, gradually losing its details until it finally became little more than a visual schema.

ing this letter I associated it with the deaf and dumb alphabet in which the 'f' is made by passing the right palm quickly in a straight line across the up-turned left hand. That gesture came up in a flash of motor imagery when you mentioned the name."

42. Feb. 17, 1913. 'f,' 3 sec. (6th. presentation.) "That is 'f.' As soon as I got the tactual and kinaesthetic perception of the dots, arranged in a straight line, I had a kinaesthetic image of that manual motor movement which represents 'f' in the deaf and dumb alphabet. I also visualized my hands making the movement, then the 'f' came as a vocal-motor innervation. The whole experience seemed very familiar."

43. Feb. 24, 1913. 'f,' .8 sec. (7th. presentation.) "I got a tactual perception of a straight row of dots, a motor image of the movement for the 'f' of the deaf and dumb alphabet; and I named the letter immediately, with full certainty."

The Recognizing of Olfactory Stimuli

44. Jan. 31, 1914. Trèfle, 4 sec. (2nd. presentation; 1st. recognition.) "Trèfle. First I was aware of the fragrance of it in terms of attention to the odor itself. I was aware that it was a stronger and more intensive fragrance than the first I had had. That was an interpretation of a state of attention to the intensity of this odor itself, other things not being in consciousness. I do not think that I was actually aware of what I was comparing it with. Then there was the briefest possible visual image of a bottle inclosed in a basket casing which I now know was the same one I had associated with the word 'Oriental' once before. That seemed to function as a consciousness that it was not one of my distinct flower odors,—a consciousness, largely of the fact that more flower odors occurred to me as a possibility. As the word 'Trèfle' appeared it was unhesitatingly spoken. It appeared in auditory and vocal-motor verbal imagery; I was neither sure nor unsure; it was not a genuine recognition. I am not very certain. It seems that perhaps Trèfle was the first of this series that occurred and I spoke without thinking, almost. What I mean is that I can not characterize my certainty at the time because there was neither uncertainty nor certainty."

45. Feb. 7, 1914. Trèfle, 19 sec. (3rd. presentation.) "I think I said that was something that contained the least suggestion of cologne about it before. Marked recognition of it as a perfume. I was aware of a little tension, very slight, located largely in the throat, above the vocal organs. First I got the whiff and then this tension disappeared and there was a tendency to take the bottle away from my nose. Almost immediately started to say the word 'what' with renewed and much more keen attention to the odor than ever before. Took a deep whiff of it. No name whatever occurred and I was aware of slight unpleasantness and tension. Then I held the bottle down at my knee for a moment, all this time trying to think what it might be. Aware of this suspension in consciousness and this tension. Did not make any effort to reconstruct the past series. Then smelled the thing again, attending now to one thing and now to another. Tried to get an identifying quality but without success. Finally I thought I detected a slight suggestion of freshness that either I told you about or registered mentally as a criterion for one of these odors. That came simply as a visual image of a cologne bottle."

46. Feb. 14, 1914. Trèfle, 10 sec. (4th. presentation.) "Very uncertain, but it might be one of those violets. First of all I was aware that it was a fragrant odor and there was a slight pleasantness connected with that. That was purely in the nature of the smell. I found myself taking rather a deep whiff without any special effort to determine what it was; it was rather a mechanical response to the general situation of having the thing in my hand. Toward the close of that whiff, I became aware of the problem in hand. That was in a marked concentrating of my attention much more closely upon the smell, in a cessation of pleasantness, and I think a general but very slight kinaesthetic pulling up to the task, or readjustment. I should not say general,—it was localized in my chest and trunk. Then my attention singled out a very slight something which increases the violet quality. That is simply in terms of attention to an aspect of the smell. The word 'violet' occurred without any particular inflection,—either questioning or decision. There was another alternative. Almost immediately I became aware of a vague spatial schema,—I seemed to be attending to a grayish visual splotch, to the left of which was another very much less distinct splotch. That state of affairs was a consciousness that the odor was not very well identified as violet and that it might belong to that group of non-flower odors. I never reached any great degree of certainty."

47. Feb. 21, 1914. Trèfle, 12 sec. (5th. presentation.) "There was a short period, at first, during which I was adjusting myself to the fact that the odor was a perfume. I simply did not try to select out any characteristic quality at the outset. I soon began to do this and then had a peculiar schematic consciousness of discarding all the flower odors. This came in visual imagery of a table, with about twenty-five bottles on it. (I did not recognize it then, but now I know it was a Wellesley scene.) Then these receded as though pushed away by an arm,—which, however, I did not see. All the time my attention was partly occupied, too, by a non-flower-like quality in the fragrance. I then took a deep whiff, and the word Trèfle appeared. Still I did not have a tendency to turn away from the problem, as happens when the name comes with great subjective surety. I smelled it once more, and was aware of a certain delicacy in the fragrance. Then I said, 'That's Trèfle,' exhaled my breath, and relaxed. I was sure I was right."

48. March 14, 1914. Trèfle, 2.2 sec. (6th. presentation.) "Is that Trèfle? Took a fairly deep whiff of that,—the rather strong non-flower quality of it stood out. 'Quelques Fleurs' occurred for an instant in clearly auditory terms,—possibly visual, too. Immediately I attended away from the Quelques Fleurs. Then the word 'Trèfle' started to say itself. Barest sort of set of the mouth for the 'T' sound. Then a little catch of the breath and I asked very suddenly, 'Is it Trèfle?' There seemed to be no affective toning in that experience. It was more a sort of suspense, waiting for the answer. Of course the awareness of the perfume was present all through this."

49. April 4, 1914. Trèfle, .8 sec. (7th. presentation.) "That is Trèfle. That was an immediate recognition. The odor was mild at first. While I attended to it carefully I did not get a very satisfactory whiff of it until rather late in the first whiff. Just as soon as it stood out my attention focused on a peculiar quality of mildness,—lack of that overpowering sweet quality. This had a milder and different quality. My attention pounced on that. It stood out very suddenly and I said afterwards 'That is Trèfle?' The words

seemed to come spontaneously and I said them with an inflection of certainty."

Observer W.

The Recognizing of Visual Stimuli

50. March 7, 1913. Della Robbia 'N,' 10 sec. (2nd. presentation; first recognition.) "The moment I perceived it, there was a slight familiarity; a whole mass of associations came in. There was a visual image of an 'N' I had before today; then of another 'N'; then I went through the list of types. 'American Typewriter' was present to consciousness for the briefest space of time in visual imagery. Then I visualized the name "Della Robbia' printed in small (lower case) letters. My attention turned from that to Clearface and I became aware of 'Clearface' in vocal-motor terms with a questioning accent. Then a visual image of a Della Robbia 'S' stood out in consciousness and seemed exceedingly familiar,—the serifs were just like those on this 'N.' I visualized both and said 'Della Robbia' instantly.

51. March 14, 1913. Della Robbia 'N,' 2 sec. (6th. presentation; second recognition.) "I noted during the presentation that the lines were of uniform thickness, and that the letter was large. That was followed by an intense strain in my vocal-motor apparatus, which meant that I knew the type and had a keen desire to say something, but I had absolutely no idea of what the name was. Then a visual image of the two 'l's' and the two 'b's' of Della Robbia rushed into consciousness and touched off my vocal-motor response 'Della Robbia.'"

52. April 24, 1914. Della Robbia, 'N,' 1 sec. (7th. recognition.) (Recognitions three to six were practically identical with that quoted above.) "I noted that the lines were uniform, and that the letter was large. First there was a sudden increase in my familiarity with a movement of my lips to say 'Bulfinch.' Then I had a visual image of two 'b's' and I immediately said 'Della Robbia.' Tension was instantly relieved."

The Recognizing of Auditory Stimuli

53. Jan. 17, 1913. 'Overture 1812' (Tschaikowsky), 10 sec. (3rd. presentation; 1st. recognition.) "When the music first began, I was aware of the character of the music as such,—it was fast and confused. I was conscious, too, that my attention was not very alert at this time. The next thing I perceived was the beat of that rhythm, this perception seeming to consist in an ability to anticipate the note in auditory fashion. A slight feeling of pleasure accompanied this. Then suddenly, I was aware of the *Aufgabe,* which seemed to be present as an effort of keener attention. Several successive visual images now came in; the first was the word 'Tschaikowsky'; next the word 'Danse Trèpak,' accompanied by a fleeting visual image of a Russian dance. There was now an increased familiarity which seemed to be associated with the image of a piece of paper localized off in space, but no word was perceptible on it. I thought I knew what the name was, however, this being present in a faint visual image of 'Tschaikowsky' off in the fringe of consciousness, located at the left. I was conscious of kinaesthetic sensations in the region of my mouth which was opened as if to say 'O.' Then suddenly I

found myself pronouncing 'Overture' and immediately 'Overture 1812' appeared upon my visual image of the piece of paper. My reaction then followed in mechanical fashion."

54. Jan. 20, 1913. 'Overture 1812,' 5 sec. (2nd. recognition.) "When the music began my attention was diffuse. I noted the accompaniment in the bass and it seemed slightly familiar. I found myself attending closely to those chords; I visualized them on a manuscript. At the same time, I recalled having heard such chords before,—this is an association of my manuscript image, with faint visual images of the situation here in this experiment on two former occasions. I then anticipated, in a clear auditory image, a phrase in the treble which is my criterion for this selection. When the anticipated phrase came, there was a relaxation, together with a visual image of 'Overture 1812' in your handwriting, a short distance out in space in front of my eyes."

55. Feb. 17, 1913. 'Overture 1812,' 3 sec. (3rd. recognition.) "The music at first did not bring any familiarity. I seemed scarcely to perceive it. Suddenly an awareness of the auditory impression rushed in upon me and I hurriedly went over the music I had already had, with auditory imagery of the air in the treble and of the accompaniment in the base. It was now very familiar. Vocal-motor image 'Overture 1812' followed by 'Tschaikowsky' rushed into consciousness instantly and I was aware of a relaxation of tension."

56. Jan. 20, 1913. 'Il Trovatore' (Verdi), 2 sec. (5th. recognition.) "My attention was keen when the music began. I was instantly aware of that chord which stands out in the bass, in four beats. Not more than two chords had been struck in the accompaniment before I anticipated the rest of the measure in vocal-motor auditory imagery. This made me absolutely sure that it was the 'Il Trovatore' selection, and all tension relaxed."

The Recognizing of Tactual Stimuli

57. Nov. 21, 1912. 'y.' (This letter is represented by three raised dots, arranged in the form of an equilateral triangle, with its apex above a horizontal base.) 26.4 sec. (2nd. presentation; 1st. recognition.) "When I first explored the dots, the word 'new' came to consciousness in vocal-motor imagery. At the same time I was dimly aware of a number of past experiences with these letters,—'z' and 'c' appearing fairly clearly in visual imagery. I associated the stimulus with 'z' at first, visualizing the dots on the lower line as three in a straight row. Then I visualized the upper line of 'z' and explored for it with my finger. But I could find no upper line in the stimulus, and 'z' dropped out of consciousness. Next a visual image of a typewriter 's' appeared but it seemed new and strange and it in turn slipped out of mind. All the time my visual image of the arrangements of the dots was clearing up; when it became definite, a visual image of a type 'y' stood beside it and I reacted. Later I recalled going through this last process in learning it before."

58. Dec. 6, 1912. 'y,' 5 sec. (4th. presentation.) "With the first tactual impression, I visualized a triangle having two long sides, and a shorter one to the left. Then, a visual image of 'y' appeared as though superposed upon this triangle. This experience was rather unpleasantly toned, and the words 'more time' came to consciousness in vocal-motor imagery which, together with a more deliberate exploration of the stimulus, meant that I must examine it more closely.

My visual image of the group of dots became clearer, and my familiarity greater. My triangle became equilateral, with its base toward me; and a visual image of 'y' appeared beside my image of the dots. This, together with a memory image of myself sitting here before, completed my recognition."

59. Feb. 14, 1913. 'y,' 2.8 sec. (6th. presentation.) "On first getting the tactual impression, I had a vocal-motor image of 'v' with a visual image of these three dots arranged in triangular form, but no definite localization of the base or apex. This visual image, however, cleared up immediately and the base was toward me. Then a visual image of 'y' appeared and my attention turned to you."

60. Feb. 21, 1913. 'y,' 1.6 sec. (7th. presentation.) "I immediately visualized the stimulus as a triangle with its apex upward, and said 'y.' That was all,—no visualization of the type 'y' and no feeling of familiarity. Whole experience seems automatized."

The Recognizing of Olfactory Stimuli

61. Jan. 24, 1914. Coast Violet, 9 sec. (2nd. presentation; 1st. recognition.) "It is familiar but I can not get its name. Attention lingered upon the actual quality of the sensation only for an instant. The sensation seemed to be of slight intensity and was visualized, at the opening of the nostril, as a little amorphous gas. Immediately following this came a series of visual and vocal-motor imagery. First the visual, in which I saw a portion of ground and on it was a plant just coming up, something like a skunk cabbage; its top was chopped off. Vocal-motor strain to say something and there was nothing to say. Strain was so intense that attention shifted for an instant to a visualization of my speech apparatus, with muscles in state of contraction. Only thing that came in was the word 'herb' repeated two or three times. General physical state of tension, localized in the speech apparatus, and about the face. These processes, together with the accompanying pleasant affective toning and the absolute predominance of this imagery,—the abandoning of everything else,—was the structure of this familiar toning. It was a one-level consciousness. The visual image of this stump and the vocal-motor 'herb' were so intense and clear and sudden that it made the familiarity a very intensive experience, though I can not name the perfume."

62. Feb. 7, 1914. Coast Violet, 15 sec. (3rd. presentation.) "I have not the slightest idea what it is. I visualized, in the fore-period, the processes of putting it up to my nose. I was aware of the *Aufgabe,* in auditory vocal-motor imagery: 'See if this is familiar.' The sensation first came as a strong, penetrating odor. It tickled the membranes of my nose and had a slight oily quality. The sudden attraction of attention to the quality and the persistence of that quality in the perception; a welling-up of pleasant affective toning, plus a mass of imagery of previous sittings which came in just like a flash; an actual memory-image of that same odor before,—all that stood out; and I interpreted the whole experience as familiarity with this odor. The word 'Quelques Fleurs' appeared in auditory imagery almost as soon as I perceived the pungent, oily quality, but I have never associated that oily quality with Quelques Fleurs. For a few seconds I was aware of the *Aufgabe* to try to get the name of it. This consisted in vocal-motor 'get the name.' Then followed series of visual images of bottles lying on the table; and snatches of auditory imagery: Rose, Coast Violet, Acme Violet,' but with faint olfactory

imagery of violet-like odors. Then it was all off, because I laughed. These images died away and no more came in and all I was aware of was strain and the occasional presence of the Aufgabe to find a name. Attention lingered on these processes for a while and then I said I had forgotten what the name of it was."

63. Feb. 28, 1914. Coast Violet, 13 sec. (4th. presentation.) "The odor immediately gave rise to memory-images of former sittings in this experiment. Its quality was unpleasantly pungent, and I experienced a motor tendency to recoil. Then I began analyzing the sensation, and noted that it seemed oily. I visualized it as something greasy on the inner membranes of my nose. The experience now became pleasant. There was a lot of ill-defined imagery of former experiences in this room,—visual, olfactory and auditory,—and I heard myself saying, 'Why, yes, I know that. What's its name?' There followed imagery of your voice saying 'Trèfle; Coast; Acme,' and others. Then came visual images of a big herb, like a skunk cabbage, growing out of the ground. Auditory imagery of the words 'herb' and 'Coast' persisted in appearing and I said: 'This must be the one.' Intense pleasantness now toward the experience, but immediately there appeared in consciousness simultaneously, visual imagery of many bottles, with attention moving from one to another, and an experience of doubt."

64. March 21, 1914. Coast Violet, 7 sec. (5th. presentation.) "I am not certain of my identification. Very little imagery. Nothing called up. I found my attention shifting from the bottle in my hand to the actual olfactory sensation itself. I found myself attending to a sort of pungency with a violet-like quality which came to me somehow associated with a visual image which seemed to be like a purple dome. The presence of a little off-shoot in this dome, with a kinaesthetic image of jumping back, was the structure of what meant to me 'there is a new factor which I did not distinguish before.' This intensive experience was folowed by a faint visual image of a patch of ground with an herb coming up. Then that faded out and my attention was entirely taken up with the experimental surroundings."

65. March 28, 1914. Coast Violet, 14 sec. (6th presentation.) "It is as familiar as can be, but I can not be sure of the name. The first name that came was Coast Violet. Another possibility was Trèfle. Those were the two clearest ones. Very keen concentration of attention. Auditory *Aufgabe:* 'Now get the essence of this' with concentration of attention upon it. First I took a long, deep whiff, and I was distinctly conscious of doing it; it seemed to be an activity directed by the *Aufgabe.* Visual and auditory imagery followed in rapid succession, accompanying this deep inhalation. My attention went to the particular quality of the olfactory sensation; this was almost a visual and cutaneous thing. I had a visual image of a film, very thin and brownish, in the inner side of the left nostril. It was smooth and shiny and that with the peculiar contraction of the tongue in the back of the throat, and also a contraction of the diaphragm meant to me this pungent odor. But almost immediately following this there was auditory image 'pungent'; then attention shifted to another aspect of this quality. It seemed watery and almost gaseous; reminded me of illuminating gas. This was immediately followed by a visual image of a surface of the ground; saw lot of plants coming up; did not know what they were but I know now that they were skunk cabbages; saw them lying there among moss and wet leaves.

This was immediately followed by an auditory image, turning into visual, of Coast Violet. Then there was an experience of doubt. I could not seem to leave the problem. Memory images of past experiences persisted to demand my attention."

66. April 4, 1914. Coast Violet, 2 sec. (7th presentation.) "That is Coast Violet. At first I was not even aware that it was a perfume. I noted that the sensation was weak, and I inhaled deeply. Then I felt a sort of contraction in the back of my throat and tongue; this sensation seemed to extend to my diaphragm. Then I visualized an oily surface low in my nostril. The experience became very pleasant. Almost simultaneously my attention fastened on a visual image of a meadow, which seemed at my very feet, and in which were some hazy, ill-defined plants, which, I suppose, were my skunk cabbages. But instead of attending further to them, I found myself experiencing more intensive sensations in my stomach and diaphragm, and these were superseded by a visual verbal image of Coast Violet, the Coast appearing very prominently, written in white on a black background. I settled back in my chair with great satisfaction as I gave the signal-tap."

Observer V.

The Recognizing of Auditory Stimuli

67. Dec. 9, 1912. 'Brautlied' (Goldmark), 20 sec. (2nd. presentation; 1st. recognition.) "The air seemed slightly familiar from the first. My familiarity with it seemed to consist in the clearness of my perception of the sound, together with kinaesthesis in my entire body,—swinging to the rhythm. An impulse to react, consisting of a series of tactual images of pressure on the key, was inhibited,—no name having yet come to consciousness. Then my attention was concentrated on the stimulus, and when that little "skip" in the music occurred, it brought a vocal-motor image of 'Bridal Song.' I reacted to that, and then ceased to attend to the thing."

68. Jan. 28, 1913. 'Brautlied,' 10 sec. (3rd. recognition.) "It was familiar from the first, the thing clearest in consciousness being my attention to the stimulus and my inhibition of a strong tendency to react." (The hand was poised over the reaction-key in a tense position.) "I visualized a threshold with a pair of feet in white satin shoes skipping over it. Then came a change in my kinaesthesis,—innervation in my feet and changed respiration. There was a pleasant affective toning and vague vocal-motor and auditory images of the act of describing something like this before. My reaction was followed by marked relaxation."

69. Feb. 25, 1913. 'Brautlied,' 5.4 sec. (5th. recognition.) "The familiarity came first as the memory-image of my kinaesthetic adjustment to this air,—that peculiar experience of thinking that you have done something years ago in exactly the same way in which you are doing it now. Just before I reacted, there was a visual image of a low door-step and a small white foot just going over it. This visual image was supplementary, I think, and more or less irrelevant to the familiarity itself, which consisted in kinaesthetic adjustment, followed by relapse of tension."

70. Feb. 25, 1913. 'Danse Trèpak' (Tschaikowsky), 2 sec. (5th. recognition.) "Immediately on noting the stimulus, my whole body seemed to sway in motor imagery, which was so clear as to seem

almost like actual movements. The facility and clearness of my perception of the music, together with this motor response, constituted absolute familiarity. 'Danse Trèpak' in vocal-motor terms immediately followed this experience."

The Recognizing of Tactual Stimuli

71. Nov. 21, 1912. 'a,' 4 sec. (4th. presentation; 1st. recognition.) "There was a slight familiarity as soon as I got my tactual perception of the dots. I was impelled to count them, however. My attention was held involuntarily to that activity. I explored the dots one at a time. Then I got a visual image of two dots which seemed to be perfectly familiar, though no names presented themselves,—and, indeed, no name occurred until I actually said 'a.'"

72. Dec. 6, 1912. 'a,' 3 sec. (5th. presentation.) "I had an anticipatory visual image of two dots when my finger touched the first one. There was a vocal-motor image of 'a,' followed by a vocal-motor image of 'e.' My attention again fixed on the visual image of the two dots, and I reacted to the vocal-motor 'a,' which then became focal in consciousness."

73. Jan. 31, 1913. 'a,' 1 sec. (6th. presentation.) "The tactual sensation was immediately familiar,—the tension all over my body was instantly relieved. Then there came to mind a visual image of a large, black capital 'A.'"

The Recognizing of Olfactory Stimuli

74. Feb. 23, 1914. Quelques Fleurs, 4.8 sec. (2nd. presentation; 1st recognition.) "The first thing of which I was conscious, after sniffing the odor, was intensely pleasant affective toning. Am sure of quickened heart action and increased sensation of warmth, beginning about the middle of the torso and proceeding upward. Then the name 'Quelques Fleurs' came, visually, printed in violet colored, rather fancy letters. My attention was narrowed intensively, and when I reacted, there was a distinct sense of relaxation."

75. March 1, 1914. Quelques Fleurs, 6 sec. (3rd. presentation.) "I recognized immediately that it was a perfume, and very pleasant. This recognition and a feeling of confidence that I could identify it was present, I think, just in the manner in which I put the bottle up to my nose for a further examination of the odor. On getting a clear perception of its quality, the word 'Quelques' appeared in Japanesey letters, on a large, cut-glass bottle, of which I saw only the neck and the stopper, which was frosted. Then I said 'Quelques Fleurs,—that's my favorite of all your perfumes.'"

76. March 3, 1914. Quelques Fleurs, 2 sec. (4th. presentation.) "A strong feeling of pleasantness accompanied the sensation. At first, my attention seemed very diffuse and I was aware only of the odor quality and of its great pleasantness. Then suddenly 'Quelques Fleurs' rushed into mind in vocal-motor imagery, and I knew this was a familiar odor, and reacted immediately."

77. March 22, 1914. Quelques Fleurs, 2.6 sec. (5th. presentation.) "That was an experience of immediate and direct assurance. Strong pleasantness was the first thing in consciousness, after a perception of the odor quality. A deep intake of breath followed, and a visual image of an advertisement for Quelques Fleurs which I saw in '*Life*' last week. There followed an auditory image of my own voice, saying, as I then said, '*Now*, you've got it in print, after all those

visual images you've had of it. Quelques Fleurs.' Then I pronounced it aloud. But all of this last was quite incidental to the recognition, which was complete when I took the deep breath."

Observer B.

The Recognizing of Auditory Stimuli

78. Dec. 5, 1912. 'Il Trovatore' (Verdi), 6 sec. (3rd. presentation; 1st recognition.) "The first note seemed to draw my body over toward it. I experienced a motor tendency to keep time, an innervation of the throat as in humming, and kinaesthetic imagery of swaying with the rhythm. Then I went back in memory, to my first sitting here, for a name,—this in visual imagery of the situation here. A momentary search, an attitude of listening, and 'Trovatore' came to mind in auditory imagery."

79. Jan. 9, 1913. 'Il Trovatore,' 3 sec. (2nd. recognition.) "That was familiar immediately; my attention was narrowly focused, my breath was held, and I was conscious of muscular tension all over my body. The whole experience was pleasantly toned. As the first note ended I had a flash of auditory imagery of the next tone, which was swamped immediately by my perception of the tone itself. Tension instantly ceased. The name which then came in auditory vocal-motor fashion added nothing to my surety."

80. Jan. 23, 1913. 'Il Trovatore,' 1 sec. (3rd. recognition.) "The familiarity with that was perfect from the first perception. It seemed to consist in the clearness and the directness of the perception itself. There was the merest intimation of kinaesthetic imagery of swaying with the rhythm, followed by relaxation and turning to introspect."

81. Jan. 30, 1913. 'Rigoletto,' 15 sec. (1st. recognition.) "My experience consisted of a perception of the tone quality and phrasing, together with a flash of visual imagery of a previous sitting in this room. I seemed to grope over in the direction of the table (where the experimenter always sat) as though to get the name from over there. My visual schema was present, too,—that image of four gray blotches descending obliquely toward the right, on a lighter gray background, and ending in a curving line. There was a motor experience also, in this schematic imagery. I seemed to move with the blotches and the curved line. When the phrase which fitted into this schema was played, the name 'Rigoletto' sprang into consciousness, in auditory vocal-motor imagery."

Observer O.

The Recognizing of Olfactory Stimuli

82. Jan. 31, 1914. Amyl Alcohol, 3 sec. (2nd. presentation; 1st. recognization.) "On perceiving the stimulus there was a recognition process which was very intensive; it seemed to be an organic drawing up in the upper part of the diaphragm, together with vocal-motor imagery of 'That's the one.' Sensation seemed to grow increasingly intense; it seemed to increase way back in the back part of the nostril. Vocal-motor imagery 'alcohol' came up and then vocal-motor 'Oh, I don't know whether it is Ethyl or Amyl alcohol; but I know the odor.' That came in scraps like 'Amyl, Ethyl,—don't know; anyway, it's that one,' which meant it was the one which

made me cough. Slight, pleasant affective toning accompanied by vocal-motor 'Well, I know that, but I don't know its name.'"

83. Feb. 7, 1914. Amyl Alcohol, 3 sec. (2nd. recognition.) "In the fore-period, I had a vague visual image of my hand holding the vial and it seemed to be a visual image of motion,—just a line very slowly drawn toward me. There was a very quick recognition process, though the name did not come to me. It consisted in a very clear and precise percept of the odor, accompanied by vocal-motor 'one of the old ones' and also 'one of those bad ones.' I could not name it. There was vocal-motor 'one of the alcohols?' Then there was a pause and during that pause the unpleasant affective toning continued. There was strain in the forehead. Vocal-motor imagery of 'what, which one?' There was no answer to that and the last thing in consciousness was that 'what, which one?' all accompanied by unpleasant affective toning."

84. Feb. 14, 1914. Amyl Alcohol, 1 sec. (3rd. recognition.) "On perceiving this there was unpleasant affective toning which lasted only a very short time. Then there was a quick change to a pleasant affective toning and a vocal-motor 'Oh, there it is,' and 'that is the bad one.' That completed my recognition. 'What's its name? Is it Amyl? Yes, Amyl,' followed, in vocal-motor imagery."

Observer S.

The Recognizing of Olfactory Stimuli

85. Feb. 7, 1914. Cresol, 17 sec. (2nd. presentation; 1st. recognition.) "The very first perception was followed by vocal-motor imagery, 'It is either Phenol or Creosote. Now which is it?' This was followed very, very quickly, by clear olfactory imagery of creosote, which was apparently quite separate and apart from the actual olfactory sensation. There was a recall, also, of the characteristic mark or sign of the creosote odor,—the peculiar way it affects the lower part of the nose and persists. I was next aware of inhaling and of letting the gas out very slowly. This was followed by very pleasant affective toning and vocal-motor imagery of 'that's it; that's Creosote.' But I couldn't let it go at that. The adjustment was not complete. It was followed by another rise in the attention wave. I was aware of a visual image of a little square bottle on which was the word 'Mapleine'[11] and I was aware then of olfactory imagery of the odor of Mapleine. This imagery was broken into by a consciousness of self and of you and this consciousness of the conditions of the problem was further developed by the vocal-motor imagery, 'Well, she would not give me that kind of an odor.' Then my attention narrowed. I was aware of unpleasant affective toning, and of the following vocal-motor imagery: 'Oh, that's all right; that's creosote, all right. The mapleine is an artificial preparation and the chances are they use creosote in making up that Mapleine.' Then my attention shifted and I turned to introspect."

86. Feb. 14, 1914. Cresol, 8 sec. (2nd. recognition.) "The perception was complete at first and persisted in great clearness. The first thing I was aware of was the vocal-motor phrase 'maple sugar.' Then there was a very brief series of olfactory and visual images, connected with the experience I had here the other day when that

[11] This observer reports that Mapleine is a synthetic substitute for maple syrup; it is characterized by a faint odor of creosote or tar.

maple sugar characteristic was assigned to the creosote. I think it was mostly in olfactory imagery. I had very fleeting visual images of the bottle marked 'Mapleine,' and I was aware of attending to a particular part of the stimulated nostril,—the lower part. Then just the words 'maple sugar,' followed an image of the Mapleine bottle and a few of the details of the former experience here. Then the word 'creosote' came automatically."

87. March 7, 1914. Cresol, 6 sec. (3rd. recognition.) "I was aware of making a definite motor adjustment to the sensation,—of breathing easily, in shallow breaths, and of attending to the lower part of the olfactory membrane. Then there was a definite awareness of attending to the persisting sensation and waiting for something to happen. Finally the words 'Oh, that's creosote,' came in vocal-motor imagery, and my assurance was complete. Later I had olfactory imagery of that characteristic maple sugar quality and then my attention was directed to an image of this Mapleine bottle. I said, 'That's creosote, all right,' and was aware then of general relaxation."

88. March 14, 1914. Cresol, 2.4 sec. (4th. recognition.) "That is Cresol. I was aware that I was inhaling and then exhaling, that the lower part of the olfactory organ was being stimulated, and that the sensation persisted after the bottle was removed. Even after I had breathed through my nose two or three times I was aware of the stimulation still there. This persistence of the sensation seemed to be the antecedent to the coming in of all the experiences I have had where the persistence was a factor. Almost the first one that came was the maple sugar. I had a very indefinite, inadequate image of a lump of maple sugar. I was aware of the persistence of the odor after I smelled it. This meant to me that this was undoubtedly the Cresol."

89. March 21, 1914. Cresol, 2 sec. (5th. recognition.) "I attended first to the characteristic quality of the stimulus. It is a queer smell quality,—coming intermittently, and affecting the lower part of my nose like little particles of dust. Its persistence attracted my attention and I was aware of vocal-motor imagery, 'that's Cresol.'"

Observer Bd.

The Recognizing of Olfactory Stimuli

90. Jan. 24, 1914. Halycon Rose, 4 sec. (2nd. presentation; 1st recognition.) "On smelling that, I had a reinstatement of the mental experience which I described at the last sitting,—an association with the odor of wild roses, and vocal-motor 'briar.' The whole thing seemed very familiar. After I reacted, I had a visual image of the part of the wild rose that is left when the petals come off."

91. Jan. 31, 1914. Halcyon Rose, 17 sec. (3rd. presentation.) "I don't know what it is. That was rather a remarkable experience. With the first inhalation of the right nostril I got the quality of the odor very distinctly but was also conscious of unfamiliarity, uncertainty. I began a second inhalation, and suddenly, during the course of that inhalation there came up a feeling of familiarity, but it was a feeling, largely organic, in the upper part of the chest and upward, —not very intensive and not definitely localized, lasting only for a brief time. With that came the vocal-motor imagery 'going to get it,'—a fragmentary sentence which indicated that I was on the point of getting the identification. Then feeling of familiarity disappeared and attention lapsed."

92. Feb. 7, 1914. Halcyon Rose, 9 sec. (4th. presentation.) "'Perfume' came immediately in vocal-motor terms, and with that a feeling of familiarity which I should say was largely organic in the upper chest region; pleasant. 'Quelques Fleurs' was present in vocal-motor terms, but I was not at all sure of my identification. Then I smelled it again. Just at the end, I got that peculiar briar quality that I spoke of the other day and immediately 'briar' came, vocal-motor, and 'rose,' vocal-motor. I am quite certain that that was rose."

93. Feb. 14, 1914. Halcyon Rose, 8 sec. (5th. presentation.) "Almost with the beginning came the word 'p-e-r-r-rfume,' drawled out in vocal-motor terms, with the inhalation. I felt myself pronounce this in that long drawl. Not aware of any specific feeling of familiarity. Along toward the finish I got a slightly changed olfactory quality; and the word 'briar' appeared in auditory terms. I am surprised at the amount of auditory imagery this morning because it is so unusual. My identification was not yet complete. I was led to suspect that it was going to be rose because of that 'briar.' Then I smelled it again. I approached that with a very definite *Aufgabe,* vocal-motor terms: 'Is it rose?' Found myself very tense and very alert and active, examining my experience very closely; but I was disappointed,—the word 'rose' never occurred after the *Aufgabe,* neither did 'briar,' simply a fairly intensive olfactory quality and not a single name associated. My experience was,—starting out with this *Aufgabe,*—a very, very definite olfactory quality, a certain tenseness, a certain disappointment, and an uncertainty."

94. Feb. 21, 1914. Halcyon Rose, 4 sec. (6th. presentation.) "The instant I began to sniff came 'perfume' and feeling of familiarity,—very intense. Then it disappeared and this vocal-motor imagery came in automatically: 'It must be briar; she has given me Quelques Fleurs; she has given me Coast Violet; she has given me Acme Violet.' That was all very syncopated. Meanwhile I did not attend to the odor at all. As yet I had not got any qualitative rose odor at all, but after that thing that I call a logical inference, suddenly there welled up that peculiar unmistakable briar quality, and I knew then that it was rose. I said 'rose' and then turned to introspect."

95. March 7, 1914. Halcyon Rose, .8 sec. (7th. presentation.) "With the very beginning of the sniff, I had a vocal-motor image of 'rose.' I continued to sniff, and the quality changed to that briar quality. 'Briar' came in vocal-motor terms, and my surety increased. The whole experience was slightly pleasant, though not markedly so."

96. March 14, 1914. Halcyon Rose, .8 sec. (8th. presentation.) "'Rose' came immediately, in vocal-motor terms, and I felt absolutely certain of my recognition of the odor. I hesitated for a moment before tapping, as though expecting that briar quality to come, but it didn't. This was simply a case of actively waiting for the quality to appear. Meanwhile, I had a distinct olfactory image of that briar quality. Yet, I was aware throughout of the actual olfactory sensation which this stimulus brought. I think it was a case of rapid alternation of attention from sensation to image. There was no affective toning."

B. The Functional Components of Recognition

a. The rôle of the Aufgabe. The essence of the process of recognition is function, not content. It is true that the content

of the act of recognizing exhibits certain interesting and important characteristics which bear a direct relation to the degree of familiarity which the object recognized possesses. But, given the same images, sensations and affective elements, together with a different *Augfabe*, a changed order of events and a new reaction to them, and the result will be a mental process of an entirely different nature. It is the pattern into which the warp and woof of sensation, image and affection is woven which gives its characteristic nature to the cloth we call recognition; and this pattern is dependent upon the behavior of attention, directed by the *Aufgabe* to recognize.

Although the *Aufgabe* was not always explicitly present, and although it was seldom focal, its influence on the recognitive experiences of our observers was evident throughout. When the observer was explicitly aware of the task to recognize, this awareness most frequently took the form of vocal-motor processes such as: 'Now, get this'; or 'What *is* this?'; or 'Is it De Vinne?'; or, more frequently, a telescoped and fragmentary representative of such a consciousness,—often a mere beginning of the word 'What?' Consciousness of diffused bodily strains, an awareness of the hand poised above the reaction-key, a tension in the vocal-motor organs,—as though they were about to pronounce a name,—these structural components were again and again described by our observers as constituting their task-consciousness or as partially composing this consciousness. Certain other structural elements appeared in individual cases. For example, *W.*, on several occasions, described an *Aufgabe* whose structure was a 'visual image of the experimenter, wearing an expectant expression of countenance.' Again (53, p. —) he was aware of his task as a consciousness of increased effort to attend narrowly. In many cases the recognition *Aufgabe* was not clearly present in explicit terms, but appeared rather in the attitude which the observer took up toward the stimulus presented. In such cases it was implicit in the sequence of noting, comparing, contrasting and the like; and in the release of tension which completed the act of recognizing, and which constituted an attitude that the task had been accomplished,—an attitude or a mode of behavior too implicit to be called an awareness.

The *Aufgabe*, explicit or implicit in the activity itself, serves to direct the attention to the characteristic feature of an object presented for recognition; to call up, in certain cases, associated imagery or other processes; to institute certain acts of

comparing, weighing, accepting, discarding, and the like; in a word, to direct the entire course of the activity.

Such dispositions, once set up, were exceedingly tenacious; and they persisted in many instances, notwithstanding opposite instructions on the part of the experimenter. Wide individual differences in such cases were brought out in a variant of the experimental procedure, where the observer was instructed not to search for the name of the stimulus presented, and not to attempt to recognize it,—but merely to perceive the object exposed and allow an entirely passive consciousness to run its course. Two of our observers found themselves utterly unable to follow this instruction. A strong disposition to identify the stimulus directed their attention in the customary channels, in spite of their attempts to inhibit this activity.

One of the most striking manifestations of the functioning of a deep-seated *Aufgabe* occurred in a still different variant of this experiment, where the letters presented in the recognition series were printed in red ink instead of in the usual black.[12] *Fn.* entirely failed to apprehend the difference in color in all of the ten exposures made in this manner. He even referred to his 'noting the blackness of the lines' in his introspection on his ninth experience with this series. Evidently, he had set up for himself an *Aufgabe* of noting the form of the exposed letters, and this operated so potently as to exclude altogether a perception of their color.

The effects of the *Aufgaben,* explicit or implicit, are discernible in every recognitive experience described by our observers. In the case of but slightly familiar material, these dispositions served to direct the attention to characteristic features of the stimulus, stimulating the revival of former experiences; they initiated various acts of comparing, contrasting and the like, which culminated in a complete change in the direction of the attention as the act of recognizing was completed. In intermediate stages of recognitions, the operation of the *Aufgabe* is similar to that just described, save that processes between the initial perception and the appropriate reaction are here telescoped or attenuated. At the final stage, the essential characteristic of the recognitive experience consists in the fact that the perception occupies the focus of attention, whence, under the direction of the *Aufgabe,* there is initiated an immediate and appropriate reaction, such as speaking the name of the object recognized, tapping a reaction-key,

[12] This variant was tried on all the observers at the close of the series of visual recognitions.

or making any other bodily adjustment which the circumstances render appropriate.

These processes are followed by a change in the state of the attention. This change consists essentially in a change in the processes which occupy its focus; the observer may turn from the consideration of the stimulus to an introspection of the processes involved in its recognition; or he may abandon the features of the object which have been focal in his activity and note others; or he may cease altogether to employ himself with the stimulus presented or the problem involved, and enter on a wholly different set of activities. The nature of the attention, as well as its direction, undergoes a variation in the moment of identification; *i. e.,* whereas it has been in a state of rapid fluctuation, over a wide range of activities, in that period of relaxation which crowns the recognition, it is now narrowed to a point of exceeding clearness and intensity. The direct product, then, of the awareness of the task is the behavior of the attention. We proceed to a discussion of this fundamental aspect of the experience of recognizing.

b. The behavior of attention. A survey of the experimental data can not fail to establish the fact that the attention exhibits a strikingly characteristic mode of activity during the process of recognition. When one compares a body of introspections such as these experiments have furnished, with introspections on other so-called higher mental processes, such, for example, as judging, willing, abstracting and the like, one is struck by the fact that the contents of all these processes bear a marvelous similarity. It is possible, however, to detect certain differences in the manner in which the content elements of the various processes function.

The introspections of our observers furnish evidence of the fact that the temporal sequence of the processes which follow a perception, their relative clearness, their duration, and the nature of the attention bestowed upon them, manifest certain characteristics corresponding to different degrees of familiarity or mechanization of the process of recognition. These phenomena are the very essence of the recognitive experience. A consideration of the mental experiences described by each of our observers will disclose the facts which have led us to this view.

a. Case Studies of Learning and Recognizing. The results of these investigations show that there is a most intimate relation between the learning procedure and the nature of

the subsequent recognition of the learned experience. In order, therefore, to account for the characteristics of any given act of recognition, it is necessary to study its genesis in the learning process. Such processes exhibit interestingly diverse features in different individuals; and it is with the hope of contributing somewhat to the study of individual differences, as well as to the envisagement of the recognitive experience in process of formation and development, that the following case studies are here appended.

Observer F.

Visual series: In learning the forms of the different faces of type, *F.* invariably fixed his attention on one or two features prominent in the appearance of each, and described them, in vocal-motor terms, throughout the entire exposure-series.

This description was usually accompanied by the name of the type in question,—the whole phrase being sometimes actually whispered, but oftener appearing in vocal-motor imagery; *e. g.,* while learning Clearface type,—a face larger than the others employed, and composed of uniformly heavy lines,—*F.* constantly repeated 'big, thick Clearface' in vocal-motor imagery. His position was tense, and gave evidence throughout of his excitement and anxious desire to master the material. The introspections (quoted pp. 324f.) show how persistently this procedure influenced *F.*'s later experiences with this face of type. Another striking instance of such influence occurred in the case of the Bulfinch type. During its initial learning series, *F.* had repeated to himself, 'This thin, too. Della Robbia thin, *same;* Bulfinch thin, varied,'—the obvious meaning of these syncopated phrases, in this setting, being that while the Della Robbia type was composed of fine lines, they were not of the same width throughout any entire letter, while the lines of each letter of Bulfinch were uniformly narrow. Until the very last, this firmly fixed association with Della Robbia persisted. It was the only face with which *F.* ever confused Bulfinch; and long after it ceased to confuse him, the association retained its accustomed place in the sequence of experiences aroused by the Bulfinch type stimulus. In his initial recognitions, *F.*'s attention first seized upon the characteristics of the letter displayed for recognition, and then turned to an active, excited process of describing these characteristics in vocal-motor terms, with momentary pauses after each repetition. If the name of a 'face' of type appeared in consciousness, he attended closely to it; the verbal characterization and the name were then

repeated in conjunction. If the excitement abated, and if his attention abandoned this procedure, recognition was experienced, and he reported his identification with certainty. In cases where no such name appeared, the observer was conscious of an active search for one (1 and 2. The second of the introspections here quoted is typical of *F.*'s method of comparing various combinations of vocal-motor cues). In these initial recognitions, *F.*'s attention was occasionally occupied with a recalled visual image of other letters, which he compared or contrasted with the percept which he was endeavoring to identify.[18]

As the material became more and more familiar during the successive presentations, processes of comparing the percept with reproduced imagery gradually decreased in number, so that in the several phases of what may be termed the intermediate stage in the mechanization of a recognition, such comparisons appear less and less frequently. In the last of these phases,—a level at which the recognitions may be called 'final,'—*F.*'s attention seized immediately upon the characteristics of the letter displayed, and then turned to a vocal-motor image or verbal characterization, plus the name, *e. g.*, 'funny—Bulfinch.' The problem was then abandoned altogether.

At each of these levels, *F.* was aware of the fact that the stimulus was familiar. Introspectively, he could not abstract this awareness from the succession of processes which appeared in each case. He was conscious of the longer duration of the activities preceding the signal reaction in those cases where he had a consciousness of familiarity.

In the mechanized stage, where no "feeling of familiarity" was aroused, the succession of component processes was still further syncopated; here the appropriate motor response followed immediately upon his attentive perception of the stimulus. No awareness of familiarity or of 'surety' occurs in introspection 4 (p. 325). The distinctive awareness of "known," usually called the "feeling of familiarity," disappeared as the reaction to the stimulus became mechanized. On being asked, in several such cases, if the letter seemed

[18] An illustration of this procedure, which, however, was not typical for this observer, is furnished by the following introspection: March 15, 1913. Bulfinch 'F.' "I was immediately aware of vocal-motor imagery: 'It is that funny one, the last one,—funny Bulfinch.' But just before that last phase came in, I had a clear visual image of Bulfinch 'F' and 'E' with their characteristic points, the 'E' being especially clear. Then I was again aware of the exposed letter and I reacted with certainty. Release of tension."

familiar, *F.* replied, 'There wasn't time. I just reacted automatically. Afterwards, I recalled other things about it, and it seemed very familiar.'

Auditory series: *F.*'s method of learning the airs played to him was distinctly different from that which he employed in mastering the visual material. First of all, his attitude was characterized by less strain and anxiety. He was confident of his ability to perform the task set creditably. This statement is based on data of two kinds: 1, the observer's overt behavior, which was marked by an easy, relaxed sitting position, a serene and often smiling countenance, and an absence of verbal or other expressions of discouragement; 2, his introspections, which show that instead of actively seeking associations between the music and its name, he usually listened with enjoyment, often tapping his foot, swinging his arm, or otherwise imitating the rhythm, and frequently humming along with it. The humming was usually in imagery,—vocal-motor and auditory,—though actual innervations were sometimes noted. Visual images of singers, orchestra leaders, dancers and, still more rarely, of musical instruments were aroused from time to time; but though these played a small part in the initial recognitions, they quite disappeared before the mechanized stages had been reached. In learning the selection whose recognitions are quoted (p. 325), *F.* invariably associated with certain bars of it, the words 'Hail, Pennsylvania,'—words which occurred, with the same air, in one of his college songs. As his introspections show, this association invariably played a prominent rôle in his recognitions of the selection.

F.'s initial recognitions of these airs were characterized by an attention which vacillated between the stimulus itself, and imagery of humming the air, or pronouncing its words or name. A consciousness of bodily tension which finally gave way to relaxation, constituted the background of all these experiences. A reduction and telescoping of these processes, and an abbreviation of their duration mark the intermediate stage; while in his final recognitions, *F.*'s attention shifted instantly from the perception of the stimulus to some appropriate motor response, which, in turn, was followed by a sense of relaxation.

Tactual series: In trying to learn the New York Point letter symbols, *F.*'s attitude was very like that which was present in visual series. His attention was narrow, his position alert and tense. His procedure consisted in passing his finger-tips

repeatedly over the group of points composing a given symbol, meanwhile repeating, either in vocal-motor movements or imagery, the name given to the stimulus by the experimenter. The number and arrangement of the points came to his consciousness in terms of tactual and kinaesthetic sensation. He very rarely visualized these stimuli, and visual imagery turned out to be an almost negligible factor in his subsequent recognition of them.

On perceiving the general form of the tactual material, *F.*'s attention, in his initial recognitions, turned to imagery (usually tactual, though sometime visual) of groups of dots, which he proceeded to compare with his present percept. This first stage was never of very long duration, and soon gave place to a type of consciousness in which *F.*'s attention turned directly from the perception of the stimulus to the name which had been associated with it in the past. A consciousness of strain, followed by distinct relief, completed the experience.

Olfactory series: F.'s dependence upon vocal-motor cues was strikingly shown in his procedure during the learning of the series of odors. His behavior gave clear evidence of his firm belief that he would succeed very indifferently, if at all; and his introspections give ample testimony of this disbelief in himself. Throughout the presentation of any odor for learning, he sat tense and sniffed vigorously at the stimulus, meanwhile repeating its name, and usually its striking characteristics over and over, in vocal-motor terms,—usually imaginal. For example, in learning Ethyl alcohol, he characterized it thus: "Cool; tickles in *nose,* not *throat;* Ethyl," and this he repeated throughout the exposure. Visual imagery scarcely occurred during this entire series.

The olfactory material furnished an excellent means of observing the behavior of *F.*'s attention in attempting to learn and later to recognize stimuli which had little intrinsic interest for him,—stimuli of a modality in which he believes himself poorly endowed and which furnishes him with few, if any, images.

His initial recognitions describe an awareness of attentively hurrying from the sensation under investigation to repeated reviews of series of vocal-motor images (15). His recognition seemed to depend on the reinstatement of just the proper sequence of images,—that sequence which had been adopted during the learning of the odor in question. This succession of experiences became somewhat syncopated as the odor grew more familiar; but its essential elements remained the same

throughout initial, intermediate and final recognitions. In the introspections quoted (pp. 326f.), *F.*'s characterization of the quality of the odor as 'cool in the nose,' continued to arise in consciousness as the initiator of his identification of this odor. The culmination of this experience of familiarity immediately occurred in the appearance of the odor's name, and *F.*'s reacting signal.

Observer Fn.

Visual series: In learning the visual material, this observer employed visual imagery chiefly, with vocal-motor as his only other imaginal content. During the exposure of the letters of the first type given him for learning, *Fn.* busied himself in noting the form of each letter, frequently calling up a visual image of some letter which had already been noted. When the series had been exposed as far as the letter T, he was aware of vocal-motor imagery of saying, 'I shall call this the ordinary type,—the most natural one.' As other faces of type were shown, *Fn.* constantly found himself calling up images of the letters in faces of type previously exposed, and instituting comparisons between these images and his present percept. He arranged the names of the five types in a visual schema, reading from left to right, in the order in which they had been first presented for learning; and most of his identifications were made by referring, to a given place in this schema, the letter which had been exposed for recognition. The schema was visualized, usually two or three feet to the left of the observer's eye; and the place in it which the type under consideration should occupy, stood out more clearly than the rest of the image. In his final recognitions, either an identification like the one just described took place, followed by the appearance of the name in vocal-motor imagery; or else the name of the type, in vocal-motor imagery, followed immediately upon the visual perception, which was marked by its ease and rapidity.

In the initial visual recognitions of this observer, his attention was attracted first to the size and general form of the letter; then to a rapid series of processes which had to do mainly with comparing and contrasting his present percept with certain images. A very characteristic procedure consisted in visualizing the letter in a definite place in his schema (described above), and then in making an immediate judgment as to whether or not the letter seemed to belong there. Very often, too, *Fn.* called up experiences of former sittings, and proceeded to compare the images thus aroused with the

percept now under consideration. He described the behavior of his attention as being 'sometimes active, sometimes passive,' *i. e.*, he believed he was sometimes aware of an activity and seemed to be directing the course of the processes which he experienced, while at other times he seemed rather a passive spectator of the pageant of his own ideas.

In later recognitions, processes of recall and comparison became fewer, until finally they altogether failed to appear. His attention in these cases behaved in one of two ways: after first seizing upon the characteristics of the letter displayed, it turned instantly either to a definite part of his visual schema, or else to a naming of the type,—the name appearing in vocal-motor imagery or in actual vocalization. The introspections quoted on p. 327 illustrate the changes in the behavior of the attention of this observer throughout the progressive mechanization of his recognitions of one of the faces of type.

In its final form, *Fn.*'s recognition was characterized by what he calls 'its ease and readiness' (21). Such expressions are abundant throughout his introspections, and appear always to signify an explicit mental content,—not an inferred datum. In other words, *Fn.* seemed to attend to the facility of the entrance of a percept into consciousness, as well as to the length of its persistence therein, as attributes of that percept,—components of the total experience highly important to the consciousness of familiarity.

Auditory series: Fn.'s learning of the musical selections was an exceedingly active process, rich in sensory components. Floods of imagery, visual, auditory and motor, made their appearance in consciousness. *Fn.* attends to music very analytically; he finds himself noting the phrases in auditory and motor terms, and even in visual imagery of the musical score. He frequently anticipates the phrase or phrases which are to follow.

In his initial recognitions of the auditory stimuli, also, *Fn.*'s attention was very actively employed with images, chiefly visual and auditory, having to do with former hearings of the airs, as well as with visualizations of the present auditory impressions (22). These visualizations consisted in various schemas, in gray symbols which corresponded spatially to the tonal rise and fall of striking phrases in the music. They were often ill-defined and shadowy, yet played a prominent part in *Fn.*'s earlier recognitions of these airs. If the visual schema aroused in consciousness by the selection heard was the one formerly associated with that air, a certain bodily

reaction took place,—the pronouncing of the selection's name; a tap on the reaction-key; relaxation of tension,—any or all of these. But, if some other visual schema arose before his mental vision, these 'familiarity reactions' did not follow, and no certain recognition ensued. In the experience quoted above, *Fn.*'s recognition of the air 'Brautlied' awaited, for its culmination, the repetition in consciousness of the motor reaction (looking in a certain direction) which had formerly been a part of his experience with this air.

Visual schemas played a lesser part in the intermediate levels of his familiarity with this material. In the series of recognitions quoted on pp. 327f., no visualization occurred after the first recognition. In other cases, however, the schemas persisted for various periods of time, sometimes becoming gradually less clear, and sometimes suddenly dropping out of the experience altogether. Revivals of past experiences and comparisons of them with the present stimulus were common at this stage of the experiment.

The final type of auditory recognition described by *Fn.* consisted in a rapid attentive perception of certain characteristics of the stimulus, followed immediately by a unique bodily reaction—a pervasive thrill, which seemed to be essential to his consciousness of familiarity (24) and to which he seemed always to attend.

Tactual series: In learning to recognize tactual stimuli, *Fn.* had recourse chiefly to visual imagery. His method consisted in obtaining a clear tactual and kinaesthetic perception of the number and arrangement of the dots, and then in visualizing that arrangement. Very little vocal-motor or auditory imagery was reported in any of his introspections on the learning of the letters, although the former made up a large part of the structure of his recognitions later on. *Fn.* reported more tactual and kinaesthetic imagery in his recognitions than did any other observer. He frequently remembered his former experiences with these letters in terms of kinaesthetic and tactual imagery; and, employing these same terms, he frequently anticipated the sensation which was about to be experienced when only a part of the stimulus had as yet been explored. Visual imagery is the most important structural component in the recognitive consciousness of this observer.

In his recognitions of the tactual material, we find *Fn.*, in the initial stages, attending actively to comparisons and contrasts between his perception of the presented touch symbols, and his revived imagery, both tactual and visual, of these experiences (25). Here again, visual schemas appear, in

which the letters were arranged in the order of their first presentation in the learning series. If, on the appearance of the visual image of such a schema, a given portion of it claimed his attention and stood out clearly, *Fn.* localized a visual image of the symbol which he was actually examining with his finger tips, in that portion of the schema; and his consciousness of familiarity was then intensified by an appropriate motor response.

As in the case of the auditory material, the visual schemas dropped out during the intermediate stages of mechanization; and thereafter his attention was less and less occupied with revivals of past experiences, though such processes still were a part of the recognitions at this level (26, 27).

Even in its final, or most nearly mechanized form, *Fn.*'s perception of a touch symbol was always attended by a visual image of the letter which it represented. In his recognitions of exceedingly familiar touch sensations (28), no revival of past experiences appeared. He invariably reported that he attended merely to some characteristic quality of the stimulus, to an awareness of the rapidity with which it came to consciousness: the 'permanence' of the character noted; and to the diffuse bodily thrill which ensued.

Observer Fs.

Visual series: Fs. employed both visual and vocal-motor imagery in her learning of these faces of type, often calling up visual images of other letters as the alphabet was being presented, and frequently characterizing letters, in vocal-motor imagery, as 'heavier,' as 'too fine,' etc. Her characteristic motor tendency in dealing with new material,—that is, her tendency to trace its form with the tip of the tongue against the back of the teeth,—was present in many cases.[14] Revivals of that tendency were observed in many recognitions of the same material. But by far the majority of all her recognitions included a reference to a visual schema which *Fs.* had built up during the first sitting. She described it as "five gray blotches which might be letters, located in a vertical column. They represent for me the names of the types in the

[14] The following introspection shows this process operating in a very interesting fashion. Bulfinch type had just been displayed in a learning series. "First I noted that this was a heavier type than the last. Then, with a great deal of satisfaction, I noted that I was getting a series of letters which had straight lines, of which the one on the right was always heavier. This came to consciousness in tongue movements. My tongue outlined the light lines with a slight pressure against the teeth, and then the heavy lines with an energetic stroke."

order in which they were presented the first time (Della Robbia, Bulfinch, American Typewriter, De Vinne, and Clearface). When the first place demands my attention and grows clearer, the name 'Della Robbia' appears in consciousness, immediately, in vocal-motor terms, etc." This schema became much less detailed in the later recognitions, where, indeed, it sometimes failed to appear.

When letters which had only a slight degree of familiarity were presented to *Fs.* for recognition, her attention busied itself first with a minute scrutiny of each formerly noted characteristic of the letter; next, it usually turned to an attempted recall of each face of type which had been employed in the experiment. This recall sometimes took the form of attending to vocal-motor imagery of the name of the typeface; but the moment the name appeared in consciousness *Fs.* found herself attending to the appropriate place in her visual schema of the five gray blotches, each associated with the name of one of the faces of type (29). She frequently visualized some letter of each type in its proper place in the schema, and compared its size and characteristics with those of the letter actually displayed for recognition. Sometimes the visual schema appeared in consciousness immediately upon the noting of the letter displayed; and then her attention turned to a naming of the various parts of the schema. So long as her attention was occupied in this manner, *Fs.* was uncertain of her identification of the letter under consideration; but when this activity ceased, when her attention paused for a perceptible time on some one position in the schema or on some one name, which then became clear, a final turn of attention from the problem served to make the recognition complete and certain.

As the material became more familiar, there were naturally only two or at most three possible identifications which engaged the observer's attention. There was often a confused state, a consciousness of strained activity, with some recall and comparison. Sometimes a number of images, more or less clear and detailed, occupied her attention momentarily, only to drop out of consciousness when that insignificant pause in the activity initiated her identification (30).

Finally, when perfectly familiar material was presented, *Fs.* found her attention leaping from a group of the main characteristics of the letter,—or from a perception of the particular feature which was for her a cue,—to the name of the face of type to which it belonged, or to the tap which signified her identification of the letter. The introspections (quoted

on p. 329) illustrate the typical behavior of the attention in the case of this observer, at various stages in the experiment, with visual material.

Auditory series: In the case of the auditory material, the same characteristic differences appeared in the behavior of her attention when stimuli of different degrees of familiarity were presented. When relatively new airs were played, *Fs.* found that she had attentively compared or contrasted the auditory impression with images of airs formerly heard. Visual schemas (38) and other visual images were abundant. Various names of selections played during the experiment came to consciousness, some appearing only to disappear immediately, other persisting and claiming the attention for a longer or shorter time. The turning of her attention from a name to a motor reaction (either of pronouncing it, or of tapping the key) completed her act of recognizing the air. The intermediate stages of familiarity were marked by syncopation of all these processes.

In her final recognitions, *Fs.* was conscious of an attentive noting of the stimulus, followed by an awareness of rhythmic kinaesthesis, variously localized, and an immediate tendency to tap the reaction-key. The manner in which her attention turned from clear perception to appropriate reaction, with only the slightest pause or inhibition, constituted her consciousness of familiarity with the given air (37, 39). When absolutely no pause of process intervened, the characteristic 'feeling of familiarity' did not arise.

A striking confirmation of the dependence of recognition on a particular attention-sequence is found in the behavior of this observer's attention on several occasions when new airs were introduced in certain control experiments. For example, her awareness of unfamiliarity with a portion of Traviata (40) consisted in a persistence of attention to the stimulus and a vocal-motor auditory 'new.' Rhythmic kinaesthesis was present, and even an automatic reaction-tap; but there was no recognition *Aufgabe,* and no characteristic shift of attention. In other words, her attention had not behaved in the manner customary to the act of perceiving old stimuli, and the experience of non-recognition ensued.

Tactual series: Similar functioning of the attention marked various stages in *Fs.*'s consciousness of familiarity with the tactual material. In learning the touch symbols, *Fs.* made constant use of visual and vocal-motor imagery, actually visualizing the points as raised dots, which seemed to appear

on a white background.[15] She frequently visualized, also, the letter which a particular combination of dots represented, this image usually appearing in the form of a printed letter, just above her visual image of the dots themselves. The name given the stimulus by the experimenter was repeated by *Fs.* in vocal-motor imagery; and frequently some characterization of the arrangement of the points came to consciousness in the same terms.

Another learning method in which a motor cue was the essential feature is illustrated in her experience with the symbol for " f,' which consisted of three dots in a horizontal row. She associated this with the deaf and dumb manual symbol,—passing one palm over the other. Motor imagery of this gesture was always a component of her experiences with this particular symbol.

In the initial stages, her attention was actively concerned with memory imagery, as well as with the characteristic features of the present stimulus. The consciousness of strain and of activity she called ' a persistent whatness '; it initiated her awareness that the stimulus was one with which she had previously dealt (41). This plan of active searching, image-evoking, etc. (42), became less prominent as her familiarity with these tactual letter symbols increased. Motor cues became more important in the intermediate stages; and finally, in the most nearly mechanized recognitions obtained in this series, her attention turned instantaneously from an active noting of the stimulus to some representative idea (visual or motor) of its form, and then to an appropriate motor reaction (43). The latter consisted sometimes merely in the signal-tap; but more often it took the form of a pronouncing of the name of the letter whose symbol was being investigated.

Olfactory series: When she was given an odor to learn, *Fs.* was entirely absorbed, at first, in attending to its smell quality. She endeavored to single out some unique characteristic which should serve later as a means of identification. This procedure she described, again and again, as consisting in repeatedly inhaling deep draughts of the odor and attending narrowly to its qualities. She often visualized the odor's name (which was pronounced aloud by the experimenter); and in case of what she called " flower perfumes," she frequently had visual images of flowers, perfume bottles, etc. Occasionally, the learning consisted merely in associating the

[15] These letter-symbols had been presented only in tactual fashion. The observer was blind-folded throughout, and she never at any time *saw* the group of dots.

vocal-motor auditory image of the name directly with the odor quality. In some of her early experiences with the "non-flower odors," she constructed a visual schema, not unlike that employed in her visual series, in which each gray blotch was associated with the name and the odor originally presented in an order corresponding to the series number of the blotch in question.

Her overt behavior suggested that she considered the game an interesting one, and that she viewed her own performance quite objectively. There were no signs of discouragement, impatience or anxiety.

In this observer's initial recognitions of the odors learned in this experiment, her attention was divided among many claimants. The first perception of the stimulus seemed to initiate a flood of recalled experiences, chiefly of a visual and vocal-motor auditory sort, having to do, usually, with past sittings in the experiment. An examination of the introspections quoted from this series (pp. 332ff.) shows that the certainty of a recognition bears an inverse relation to the multiplicity of processes which intervene between the perception of the odor and the reaction thereto. Her second introspection (45) contains an excellent confirmation of our contention that the essence of the consciousness of familiarity consists in the sequence in attention of processes beginning with an *Aufgabe* to recognize, proceeding to a clear perception of some distinguishing characteristic of the stimulus, and passing, after pause and tension, to an appropriate reaction. The odor of Trèfle was clearly recognized first as a perfume in just such a sequence of processes, though it was not yet familiar enough to be known as the particular fragrance called Trèfle.

The fourth introspection of this series (47) is typical of the initial olfactory recognitions of *Fs.* Here, though her attention takes the general course shown in her learning procedure, still much imagery intervenes between perception and reaction; and the result is a lack of certainty even when the correct name for the perfume finally appears.

During the intermediate stages, these associated and irrelevant processes become fewer, and less compelling to her attention (48); and by the time an odor has become exceedingly well known, such processes have disappeared altogether. We have then a rapid, sure recognition, whose essence consists in the movement of the attention, directed by the *Aufgabe,* from unique stimulus quality to appropriate reaction (49).

Observer W.

Visual series: Visual, vocal-motor and auditory imagery were almost equally important for *W.* In his attempts to master the visual material,—visual imagery being slightly favored. Every detail of each letter was noted in clear visual perception. His visual imagery consisted chiefly in revivals of letters which had formerly been presented, sometimes of the same, sometimes of different types; in retaining in memory the letter last presented (when an entire alphabet was being displayed) until the next appeared; and often in anticipating certain of the letters which were still to be observed. During the progress of these visual activities, *W.* was aware that he was describing certain characteristics of the types in vocal-motor and auditory imagery, frequently repeating, in these same terms, the name of the type which was being presented.

The attention of this observer is characterized throughout by its mobility. In his initial recognitions, with the first noting of the characteristics of the letter presented, *W.* found that his attention had turned with great celerity to a constantly shifting mass of imagery and affective toning, and that multiple activities such as comparing, discarding, accepting, contrasting, and the like, succeeded each other with kaleidoscopic rapidity. All of these activities he described in terms of kinaesthesis and attention. For example, a typical case of the activity of contrasting occurred when a De Vinne 'A' was presented and *W.* found himself attending to a hazy visual image of larger letters from which the stimulus letter seemed to emerge. This, together with a faint vocal-motor 'small' was for him a consciousness that the letter under consideration belonged to a type-face which was smaller than any other shown him during the investigation. *W.*'s awareness of these particular activities of attention,—turning now to this, now to that image, with well-defined strain, often localized in the vocal-motor apparatus,—constituted for him an experience of familiarity with the material (50). This experience was usually, though not always, affectively agreeable. In his subsequent recognitions, *W.* found that his attention was less and less occupied with revived imagery, comparisons, and the like, and that it tended to turn more quickly from the characteristics of his percept to some sort of motor reaction (51). This latter usually consisted in the actual pronouncing of the name of the typeface to which the letter belonged. The moment which immediately precedes this turn-

ing from the percept was characterized by an awareness of tension in the head or upper body, and by a sudden rise in the intensity of the impression, or,—as *W.* frequently phrased it,—by a 'consciousness of increased attention to the percept, followed by a relaxation and a complete shift of attention away from it, and toward the vocalization of something.' This 'something' proved to be, usually, the name of one of the type-faces, although the type was not always named correctly even when it had been recognized as very familiar. The awareness of the functioning of the elements concerned,—of the increased tension, the relaxation and the attention shift,—constituted the essentials of the recognition (52).

Auditory series: In learning to recognize the musical selections, *W.*'s consciousness was rich in sensory components of great clearness and detail. He usually reported visual imagery of an orchestra, or of certain instruments from which the music seemed to proceed; and he was frequently conscious of visual imagery of printed music. Remembrances of other airs, in auditory and vocal-motor terms, frequently appeared, as well as motor imagery of singing the selection which was being presented. Kinaesthesis was exceedingly important; it usually consisted of innervations of the muscles of the hands, arms, face, neck, feet, legs and chest,—their order of importance following the order named. Occasionally, kinaesthesis functioned as the only sensory component in his recognitive consciousness.

In his recognitions of the musical selections, *W.*'s attention exhibited the same general course of activity as that just described. In the earlier recognitions, while the airs were as yet only slightly familiar, it was occupied with groups of imagery and kinaestheses, groping amid multitudinous details of present and recalled experiences until some appropriate motor response ensued. When such reaction finally occurred, *W.*'s attention instantly shifted,—turning from both the stimulus and from his recent reaction thereto (53).

As the airs became more familiar, the number of activities engaging his attention became proportionately less, though here, as always, the general course of his procedure was the same, from the noting of certain characteristics of the stimulus, to some appropriate reaction to it (54).

Finally, when a very familiar selection was played, *W.*'s attention hurried from a strained noting of some striking feature of the air, of the rhythm or of his concomitant vocal-motor auditory imagery, to his usual reaction to the familiar air, complete relaxation ensuing (55).

Tactual series: W. employed little imagery other than visual in his learning of the New York Point letters. His perception of the number and arrangement of the points was obtained by means of tactual sensations, sometimes supplemented by kinaesthesis in the finger or forearm,—when he actually moved his finger over the points repeatedly and always in the same direction. The perception thus obtained was succeeded by an instant visualization of a group of dots of definite number and arrangement, and, usually, the letter for which they stood appeared beside the dots in the visual image.

In his earlier recognitions of the tactual material, besides rapidly noting and comparing the percept and the associated visual images, *W.*'s attention frequently shifted to a very complete reconstruction of one or more of the letter symbols which had been formerly presented to him (57).

As the letter symbols became more familiar, there was less recall of past situations. However, a clear visualization of the arrangement and number of points, as well as of the letter which these points represented was a necessity throughout the intermediate stage of the mechanization of the act of recognizing these symbols. The introspections show, too, that the decrease in the number of processes making up these intermediate recognitions was in the nature of a telescoping of those originally present, as the general course of events tended to remain constant throughout subsequent experiences with any given letter symbol (58, 59).

It was only in his mechanized recognitions of these materials that no visual imagery of printed letters made its appearance. Here, his attention hurried from the noted characteristic of the tactual stimulus to a pronunciation of its name. *W.* describes this experience as so thoroughly mechanized that he was not conscious of any familiarity with the given stimulus,—the reaction seemed entirely automatic (60).

Olfactory series: W. took up a rather passive attitude in his learning of the olfactory stimuli. Like *Fs.*, he seemed to find his experiences interesting and abandoned himself to them in a manner which seemed to give them, in marked degree, the spontaneity and naturalness so earnestly striven for in laboratory procedure. During the smelling of the odors to be learned, his consciousness was rich in imagery of many modalities, the visual predominating. His visual imagery was very profuse and varied. Certain images came to be permanently associated with certain odors, as, a clover field with Trèfle, a pot-pourri with Rose. Auditory and vocal-motor imagery of names and characterizations of the odors were

also abundant; and olfactory imagery was present with surprising frequency.

The most unique and characteristic thing connected with *W.*'s learning of these stimuli, however, was his tendency to localize certain odors in certain definite parts of his nose. Each, too, had its own tactual qualities. Thus, Coast Violet 'strikes low in the nostril, and is smooth and oily;' Amyl alcohol appeared to be experienced 'far back, and down in the throat'; Quelques Fleurs is 'a diffused, prickling sensation, high in the nose'; Ethyl alcohol is a 'vapor-like and watery cone which seems to start low in the nose and then to spread out.'

In learning the Coast Violet perfume, recognitions of which are quoted (pp. 336ff.) *W.* invariably perceived the pungency of the sensation in visual and tactual terms, which he described 'as visualizing the lower part of his nasal lining, which seemed to be smooth and oily.' Visual imagery of a meadow, in which plants like skunk-cabbages were growing, was also present whenever this odor was given him.

Familiarity with an odor, in *W.*'s case, was always the result of a definite sort of attention behavior: a movement in the direction invariably followed in learning the material, from *Aufgabe* to characteristic feature, thence to some striking association,—usually of a visual order,—and finally to an appropriate motor response. The latter, in this series, was often non-focal, in which case the attention had withdrawn from the problem and turned to something else, *i. e.*, the introspection, the situation, etc.

In recognitions of the initial sort, the experience was very complex; and associations and activities of many kinds found their way into the stream of attentive processes. In proportion to the interruption and delay thus caused, surety of identification became less, though the experience of familiarity was often unaffected thereby. Let the order of associations be disturbed, whether by the interference of images not formerly a part of the experience with the odor under examination, or by sensations of a new character (64), or by the absence of some important element, and the odor might not be identified at all, or might cease to seem familiar.

The dropping out of the less important elements of the original sequence of processes, did not lessen the intensity of the experience of familiarity. This is exactly what happened in the recognitions which we call intermediate (65).

In the final stages of these recognitions, the attention was still much more occupied with imagery than was the case in

any other of the materials used (66). The essential thing to note in these experiences is the movement of the attention activity from stimulus quality to reaction, the time interval between becoming less as mechanization proceeds.

Observer V.

Auditory series: During her learning of the musical selections, *V.* was constantly aware of visual imagery of unusual detail, color and variety, as well as of much emphatic innervation and imagery. The visual imagery included detailed representations of orchestras, of particular instruments, of stages set for opera, and the like. In many instances, the clang-tint of a particular instrument was represented in her consciousness by symbolic imagery sometimes accompanied by empathy. For example, the clang-tint of a bass horn in the Tschaikowsky Symphony was represented in her consciousness as a large, formless, dark, smooth mass; and accompanying this imagery was a unique experience which she described as a feeling that her own body was being expanded and diffused.

The temporal sequence of the events which occupied the focus of *V.*'s attention, together with their nature and duration, was a very important factor in each of the several stages of her consciousness of familiarity with this auditory material. In the initial stage, she was first aware of attentively noting the stimulus,—the clearness of her perception of it constituting one factor in her consciousness of its familiarity. Then her attention was attracted to kinaesthesis and organic sensations; these almost invariably consisted in internal imitations of the rhythm, and constituted her perception of that rhythm. If no name for the selection yet appeared and claimed her attention, the latter was occupied with a renewed noting of the stimulus. This stage was frequently characterized by the presence of associated imagery, which was dominantly visual (62). Some appropriate motor reaction ultimately ensued,—its implicit suitability consisting merely in the fact that on its completion her attention withdrew completely from the problem and turned to an introspection of the processes which she had just experienced.

As her recognitions became more rapid and sure, *V.*'s attention was occupied with fewer remembrances of her former experiences with the selections, though striking visual images associated with an air tended to persist and to occur in the same sequence of events throughout (68). Her attention

came more and more to shift from an awareness of a satisfactory adjustment to it, followed by organic sensations of relaxation (69, 70). The latter form of procedure is characteristic of the final form of her experience of recognition.

Tactual series: During her learning of the point letters, *V.* was actively engaged in obtaining tactual and kinaesthetic impressions of each stimulus presented, and in instantly visualizing each in turn.

V.'s experiences with the tactual stimuli were characterized by an attention behavior similar to that described in her auditory recognitions. In her initial experiences, while the stimuli had as yet no high degree of familiarity, she reported a keenly active attention, occupied with obtaining a clearer perception of the stimulus presented, and with a visualization of certain characteristics of that perception. Complete certainty, however, was not attained until a name for the stimulus was pronounced. In the intermediate stages of mechanization, her act of recognizing was characterized by a somewhat less active attention, engaged with fewer processes; a name for the stimulus here became focal more rapidly. Finally, when the touch symbols had become thoroughly familiar, *V.*'s attention leaped from her tactual perception, with its accompanying tension, to an almost instantaneous kinaesthetic relaxation,—this sequence of attentive processes constituting her consciousness of familiarity with the stimulus. The subsequent appearance of a visual image of the letter whose symbol had been presented was entirely incidental to the act of recognizing (73).

Olfactory series: V.'s learning of the odors was characterized by an eager, interested attitude. She remembers odors readily, and they are, for her, usually rich in associations. The affective toning possessed by certain of these stimuli proved to be a great aid in her later identification of them. Her procedure in learning the perfume called Quelques Fleurs is typical and I can do no better than to quote her description of it:

"In the fore-period (*i. e.*, between the pronunciation of the perfume's name and its presentation) I was visualizing the name written in Japanesey letters, and pronouncing it to myself. I also had a visual image of 'Some Flowers,' printed in bold type. When I got the odor I experienced, first, a marked degree of pleasure. Then my attention turned to a visual image of a bunch of wild flowers, violet and pink in color, with pale green leaves,—held tightly in a small hand.

I saw the tiny fingers but no thumb, and was aware of smiling with great pleasure. Then I attended to the stimulus again, but the odor seemed to take me to a forest path, with big, cool tree trunks, and large sweeps of green. It was all very pleasant. I ended by saying 'Quelques Fleurs' several times."

In all her recognitions of the odors, *V.* attended chiefly to the affective toning which each of the different stimuli aroused. In the earlier experiences with a given stimulus, her attention was next attracted to a succession of images such as had constituted her experience in learning the particular odor under consideration. These images, chiefly visual, often underwent considerable condensation and displacement. For example, color, which was associated with a boquet in learning, sometimes appeared in a recognition merely as tinting the letters of a verbal image of the perfume's name (74). In intermediate stages, such associated imagery frequently occupied her attention for only the briefest instant, and then often in mutilated, abbreviated or embellished form. The essential thing here, as in every level of familiarity, was that the attention followed a given procedure,—passing from percept through emotional toning to appropriate reaction, under the direction of a recognition *Aufgabe*. In the final stage, no processes intervened between these salient features of the experience (77).

Obsrver B.[16]

Auditory series: B.'s attention, in his earlier recognitions of the musical selections, was, like *W.*'s, first occupied in noting various characteristics of the stimulus and in comparing them with imagery of his former experiences with the same stimuli. Motor and organic phenomena occupied a prominent place in his attention activity, as also did various visual schemata (81). Kinaesthetic experiences of swaying, beating time, and the like, were frequently focal in his attention; and when present they invariably constituted an important factor in *B.*'s consciousness of familiarity (78). In his later recognitions, *B.*'s attention was less frequently occupied with remembrances of his former experiences with the musical selections. His recognitions during the intermediate stage were almost invariably characterized by the fact that kinaesthetic and organic sensations occupied the focus of attention; and these sensations were usually accompanied by anticipatory images of the air, in auditory terms (79).

[16] *B.* served only on the auditory series.

In his final experience, however, *B.*'s attention first seized upon the clearness and facility of his perception, and then turned to his customary response (80).

Observer O.[17]

Olfactory series: O. doubted his ability to learn the odors used in the olfactory series, and both his overt behavior and his introspections testify to a certain strain and anxiety in his attitude. He succeeded in mastering only a few of them. Vocal-motor imagery and affective toning proved to be his best aids to identification, and he attended to them, almost exclusively, during both learning and recognizing experiences.

The course of *O.*'s attention at different levels in the mechanizing of his recognitions of a given odor needs no special comment. An examination of a typical series of his introspections (pp. 340f.) reveals a procedure like that already described in the cases of all the observers. His early recognitions are less rich in associated imagery than are those of many of our observers, but so also are his learning experiences.

Observer S.

Olfactory series: S.'s attitude in these experiments on smell recognitions was that of one intent on an interesting and pleasant activity. He is convinced that olfactory images are common in his experience and even make up a large part of his mental life. He remembers odors readily, and finds them very potent in arousing associations.

His learning of the odors consisted in associating their names with the particular sensations and feelings which they aroused; and this process was invariably attended by detailed visual and vocal-motor imagery. Cresol, for example, was marked in his consciousness by the fact that the odor seemed always to affect a particular part of his nose, in a particular way, all of which he visualized. He noted, also, that its smell quality persisted longer than was usual with the other odors of the series; and this experience of duration seems to have been a very definite conscious datum,—an attribute of the sensation in question (85). On its first presentation, he experienced detailed imagery of a bottle of Mapleine, and of the odor of maple sugar.[18] Revivals of these images, in various degrees of integrity, persisted into the later stages of his recognitions of Cresol.

[17] Observers *O.* and *S.* and *Bd.* served only in the olfactory series.
[18] See footnote, p. 341.

In the initial experiences, *S.*'s attention was engaged not only with the location and persistent quality of the sensation, but also with detailed revivals of visual and other images which had been associated with the Cresol odor during the first learning presentation (85). As the odor became more and more familiar, this imagery became telescoped, abbreviated or lessened in amount; when the odor had become exceedingly familiar, no imagery remained. *S.* found his attention first occupied with the persistence of the peculiar tactual and olfactory qualities of the sensation, and noted the passing, with slight pause, to a motor response. In the particular case quoted, this response consisted in speaking the odor's name. A motor response of a different kind and one often described by *S.* as largely constituting his awareness that the stimulus was a familiar one, consists merely in a sudden inhibition of his inhalation of the odor.

Observer Bd.

Olfactory series: Bd. approached the problem of learning to identify odors with considerable misgiving. He was unaware, when the experiment began, that he ever experienced olfactory imagery; and he was of the opinion that he would be slow in learning the odors presented. He took up a very active attitude during each sitting,—an attitude which was dominated by his keen awareness of the task. Here is his own description of his typical learning procedure:

"I am very clearly aware of an *Aufgabe* to remember definite characteristics of each odor. This is present in vocal-motor terms; I sometimes feel myself tending to say 'very definite characteristic,' but in very much abbreviated form."

In learning the perfume called Halcyon Rose, recognitions of which are described in the introspections quoted (pp. 342f.), he says:

"I was aware of very keen concentration of attention upon the task in hand, and of the *Aufgabe* to identify the odor, which was present in the word 'identify' appearing, with a rising inflection, in vocal-motor imagery. I noted the characteristic of the odor, that briar-rose quality, and tended to repeat 'briar' and 'rose' during the sniffing."

In his initial stage of familiarity with any of the odors learned in this series, *Bd.* described partial or complete repetitions of his former experiences with the odor in question. He found his attention moving from event to event, in the

sequence which had formerly obtained. Moreover, he reported not only awareness of the succession of sensory and affective components, but also a consciousness of the nature of his attentive activity. 'I was aware of very keen concentration' is a very common phrase in his introspections; so also are descriptions of 'actively waiting,'—a state which he believed was something over and above the muscular tension involved in both.

The intermediate and mechanized stages of *Bd.'s* familiarity with this material was marked by a decreasing temporal duration, a lessening of the strain and of the searching activities. In the final stages, especially, the sense of familiarity welled up immediately (95, 96) upon his perception of the odor quality,—his attention turning almost instantly to a motor response. He again and again described his 'feeling of familiarity' as a 'complex of organic sensation and kinaesthesis, pleasantly toned, not localized at any particular point, but chiefly about the chest and upward.' The introspective evidence shows that such states are always preceded by a consciousness of the recognition-task together with a perception of sensation quality, and that they are succeeded rapidly by relaxation and shift of attention.

β. Conclusions. A survey of the introspective evidence, and of the foregoing discussion of the conscious processes which they record, leads to the following conclusions.

The mental behavior peculiar to the act of recognizing is invariably induced by a certain attitude which may be called a 'preparedness to recognize.' This attitude is the immediate result of the task set the observer. Under our experimental conditions, he was instructed to attend to the stimulus, and to decide whether it was known or unknown to him. After the first sitting, the act of merely placing himself before the apparatus was sufficient to induce a recognitive attitude. The observer was often keenly aware of this preparedness, especially in the period immediately following the 'ready' signal; and many descriptions of its structural content were given. It frequently took the forms of vocal-motor processes such as, 'What *is* it?' or, oftener still, a telescoped form of the first word only,—'Wha?' Consciousness of diffused bodily strains; awareness of the hand poised above the reaction-key; tension in the vocal-motor organs, as though about to pronounce a name; visual imagery of the experimenter's face wearing an expectant look,—these and many other processes were again and again reported as components of the consciousness of the task,—or as its entire and adequate sensory content.

When a known stimulus was presented, the preparedness to recognize, explicit or implicit in the activity itself, induced a behavior of attention which was characteristic of the recognitive consciousness. When the stimulus was presented, the attention immediately fastened upon distinctive features, or upon a distinctive feature, which had been noted previously. If the stimulus was still relatively unfamiliar, the attention was next occupied with revived associations; and it fluctuated between these and farther notings of characteristics of the stimulus, until its name appeared in consciousness, or until an appropriate reaction was made. The duration of the experiences constantly decreases.

As the stimuli grew more familiar, certain of these associative activities and components dropped out, until finally, not even the name remained necessary for complete recognition,—the appropriate reaction following immediately upon the clear perception of certain characteristics of the stimulus. Three components of the recognitive experience, however, were invariably present in orderly sequence: the preparedness to recognize; the clear perception (more or less prolonged) of some characteristic feature of the stimulus; an appropriate reaction. The absence of any one of these components, or a change in their order of appearance resulted, invariably, in an absence of the experience of familiarity. This particular behavior comprises a sequential, synthetized experience which is the consciousness of familiarity.

γ. *Summary*

1. The process of recognizing, whose essence is an awareness of familiarity, exhibited many degrees of complexity, among which at least three well-marked stages or levels were distinguished.[19]

2. Each of these three levels, which may be called initial, intermediate and final, was characterized by a mode of attention behavior which, though showing certain features common to all the stages, was nevertheless unique in certain particulars.

3. At all levels of familiarity, the attention was under the dominance of a recognition-*Aufgabe*,—a task 'to recognize.' This *Aufgabe* was often consciously present; sometimes it was implicitly present in the mode of the activities which devolved and in the reaction which completed each experience.

[19] We do not include here the level of complete mechanization, where reactions to stimuli are automatic and instantaneous, and where no awareness of familiarity is present.

4. At all levels of familiarity the attention moved, under this domination of *Aufgabe*, in a given sequence from clearly perceived stimulus through appropriate reaction to relaxation and shift of focus. This is, also, a complete description of its behavior in the final stage of familiarity.

5. In the initial stage, the attention was characterized by the fact that it dwelt longer on the stimulus quality or qualities perceived, and in that it was next claimed by acts of comparing, contrasting, rejecting and the like, having to do with revived imagery and present percept. These acts were interpolated, in the sequence described above, between the initial perception of the stimulus and the appropriate reaction.

6. In the intermediate stage, which itself often included varying numbers of levels, each marked by differences in duration and complexity, the attention to the stimulus and to processes subsequently aroused was of shorter duration. Furthermore, the processes which claimed attention became progressively fewer and more syncopated.

7. The awareness, or 'feeling' of familiarity is not a moment of consciousness, immediate and static; it is a progressing consciousness, made up of definite sequences, and including an awareness of the temporal duration of the processes preceding the motor reaction appropriate to the stimulus.

8. The actual magnitude of this temporal duration bears no constant relation to the intensity of the experience of familiarity, which requires merely that a *perceptible* time interval shall intervene between perception and reaction. When no such duration attribute is present to consciousness, an appropriate reaction to the stimulus may take place without the arousal of any "feeling of familiarity."

9. The degree of familiarity, as measured by ease of identification, bears an inverse relation to the time consumed in recognition.

C. Structural Components of Recognition.

a. Sensory components. It has already been stated that this study has demonstrated the existence of different stages or levels of familiarity, each of which is characterized by certain functional traits. Structural differences are also apparent. Obviously, since recognition is an awareness built up through successive experiences, there are no constant or sharply defined lines of separation between the stages here named and described; yet their characteristics are distinctive and have, it would seem, an important bearing on the traditional controversy as to whether or not recognition is an imageless

process. If our results have universal validity, the act of recognizing may be imageless, but may not be devoid of both imagery and sensation; and the more mechanized the process becomes, the nearer it approaches a non-sensory content. Those investigators who find that imagery is always present in recognitions would seem to have examined recognitions only in the initial or in some intermediate stage of mechanization. Such recognitions, obviously, are exceedingly numerous and important; but they by no means exhaust the possibilities of recognitive experience.

In our discussion of individual cases, under the heading of functional components of recognition, a somewhat detailed account was necessarily given of the structural components which were present in the recognitive experiences of each observer at different levels of his increasing familiarization with the stimuli employed. We refer the reader to these analyses and to the typical introspections quoted from the protocol of each observer, for confirmation of the following conclusions regarding the sensory components of the process of recognizing.

When stimuli having only a slight degree of familiarity for an observer were presented to him, his consciousness was rich in sensory components. He was aware not only of the sensations aroused by various aspects of the stimulus itself, but of a varied mass of images and sensations, sometimes affectively toned, and usually having a direct connection with his former experiences with the stimuli in question. The sort of imagery which was most abundant and detailed in such experiences seemed to be that favored in the imaginal type of the observer, rather than that of the sense modality to which the stimulus belonged.

We offer this latter point merely as a suggestive probability, —for no thoroughgoing tests to determine the imaginal types of our observers were undertaken. Such tests would have been a problem in themselves, as Fernald[20] has amply demonstrated. The imaginal type of each of our observers was roughly diagnosed from data at hand, obtained in numerous experiments in the Clark laboratory, where all had been working for periods ranging from one to four years. According to this classification, *Fs.*, *B.*, and *S.* were of the balanced type, using imagery of several modalities with equal facility; *W.*,

[20] Fernald, M. R., "The Diagnosis of Mental Imagery," *Psychol. Monog.*, 1912, XIV, I., p. 169.

V., and *Fn.* were of the mixed type, with marked preference for visual imagery; *Bd.*, *F.*, and *O.* were of the mixed type, with preference for vocal-motor imagery. *F.*'s vocal-motor preference is especially marked.

As the experimental materials became more and more familiar in successive presentations, there was a signal decrease in the amount of imagery present in the recognitive experiences. Its details, also, tended to be lessened and there were frequent examples of noticeable decay or alteration in the revived images which appeared. In some cases interesting condensations occurred, details of several images being fused into one. Organic sensations and kinaesthesis became more prominent in these mechanizing stages and the time required for each recognition grew notably shorter. Finally, when the materials were so well learned that their recognition was certain and immediate,[21] sensory content, though still present, was usually reduced to its lowest terms: an appropriate bodily reaction, often merely organic and kinaesthetic tension and relaxation.

b. Affective toning. It has long been maintained that pleasant affective toning is an indispensable component of the process of recognizing. A formidable list of psychologists supports this view.[22] James likens this pleasurable feeling to the warmth experienced on meeting an old friend. In the case of meeting, in a dark alley, a well-known enemy, this position would surely have to be defended by assuming that the glow of pleasure which is necessarily a part of the recognition is still present, but is quite swamped in other feelings aroused by this known object. In other words, the pleasure was there, but could not be felt! Happily, experimental evidence makes such logical assumption unnecessary. Affective toning appeared in less than forty-five per cent of the fifteen hundred recognitive processes analysed during these experiments; and in three per cent of these cases, the feeling was unpleasant.

Pleasantness often appeared as part of the consciousness of having successfully performed the task assigned. It also accompanied many sensations aroused by the stimuli, whether or not they were known. This was especially true in the auditory series, and in the cases of certain of the perfumes

[21] The term 'immediate' is used in its relation to the time required, and not in the sense of 'underived.'

[22] *Cf.* among others: Wundt, 58, 536; Külpe, 56, 172; Titchener, 57, 408; James, 54, 650; Meumann, 21, 40; Katzaroff, 55, 75.

used in the olfactory experiments.[23] Pleasantness was entirely lacking, however, in a great proportion of the recognitions described by our observers. It was, therefore, not a necessary component of these recognitive processes; and we believe an examination of the experiences of everyday life will justify extension of this contention to recognitions in general. The recognition of a pleasing object is a pleasantly toned experience; the recognition of a disagreeable object is often an experience essentially unpleasant. There is one case in which the latter does not hold, the case where the ability to identify the object chances to be of prime importance. In such a case the consciousness may be dominantly pleasant; but, even here, the affective toning need not be a component of the recognition but rather it may color the mental state immediately succeeding that recognition,—a state of awareness of having correctly performed a given task.

The experimental results show that affective toning is absent in so large a number of cases, in each of the levels of familiarization, that it seems necessary to assume that feeling-tone bears no essential relation to recognition, in any of its stages.

c. *Consciousness of self.* The doctrine that consciousness of self is always present in recognition has long appeared in the writings of psychologists.[24] The term 'consciousness of self' is an ambiguous one; and there is apparently no agreement as to the exact nature of such a consciousness. Titchener (57, 544) describes the consciousness of self as 'the particular combination of talent, temperament and character, —the intellectual, emotive and active constitution,—that makes up the individual mind.' The self-experience has "certain fairly constant constituents: organic sensations, a visual perception or idea of the body, and verbal ideas of 'I' and 'my.'"

Calkins, who believes that consciousness of self constitutes the background of all mental experiences, conceives the 'self' consciousness as a reality "immediately experienced as possessed of at least four fundamental characters" (46, 3). These characters are: relative persistence, complexity, uniqueness and relatedness.

[23] In some special cases, the affective toning aroused by the stimulus was attended to and made a criterion of identification. (*Cf.* observer *V.*, pp. 364 f.) This is, of course, in no way incompatible with our contention that affective toning is not an essential component of the act of recognizing, for in such cases pleasantness was as much a characteristic feature of the experience examined as was the form of a Della Robbia letter, or the rhythm of a melody.

[24] Among others: James Mill, 62, I. 329-339; Claparède, 59, 78-89; Katzaroff, 55, 78; Calkins, 46, 130.

If one adopts Titchener's description of the consciousness of self, there is certainly no warrant to be found in the results of our experiments, for making such a consciousness an essential component of recognition. A study of all the recognitions reported in our experiments yields a remarkably small percentage of cases in which the observer was aware of self, during the recognitive act. In the entire visual series, for example, *W.* was aware of 'self' in five out of seventy-three recognitions; *Fn.* described two such cases in seventy experiences; *Fs.* one out of eighty; and *F.* none at all in his fifty cases. A similar condition is apparent in the introspections on the other kinds of experimental material used.

If, on the other hand, Calkins' conception of the 'self' experience is adopted, the evidence is not quite so unequivocal. *Fn.*, for example, stated plainly that he believes that he is 'always more or less dimly aware of himself as the acting subject' in all his mental experiences. If this be the case, however, the consciousness of self is not a distinctive mark of his recognitions *per se*, but a component of all his mental activity. Moreover, the other eight observers not only did not find the 'self' a constant component, but were even convinced that it was relatively rare in their recognitive experiences.

d. *Summary.* An analysis of the data yielded by some fifteen hundred introspections upon recognition justifies a number of conclusions concerning the sensory components of the act of recognizing:

1. Sensory elements are invariably present. Imageless recognitions are not unusual in the experience of our observers; indeed, reproduced imagery is the exception rather than the rule in the recognizing of very familiar stimuli. But sensationless recognitions,—recognitive processes devoid of kinaesthesis or organic sensations, were never experienced by our observers.

2. Three well-marked stages in which the sensory content differs not only in quantity and duration but often in quality as well, make their appearance in the introspective accounts of each of our observers during his progressive familiarization with a given stimulus. These stages may be called the initial, the intermediate and the final stages.

3. In the initial stage, where recognition of slightly familiar objects takes place, the sensory content is rich and varied. The sort of imagery chiefly employed, seems to be that favored in the imaginal type of the observer, no matter what the

modality of the stimulus recognized, *i. e.*, whether it be visual, auditory, tactual or olfactory.

4. The intermediate stage is characterized by a sensory content which is less full and less varied,—the imagery of the initial stage tending to telescope, to lose detail, to alter in various particulars, or even to disappear.[25]

5. In the final or mechanized stage the sensory content is exceedingly attenuated. Imagery is often entirely lacking, though motor or organic constituents never fail to appear. When imagery is present, it tends to be of the modality of the stimulus recognized in a greater percentage of cases than is found in the initial recognitions.

6. Affective toning is not an essential component of the act of recognizing, at any of its stages.

7. Awareness of 'self' is not a necessary component of recognition.

D. Non-recognition

a. *Introspections and interpretations.* Descriptions of experiences where stimuli which had formerly been presented were believed to be new, shed much light on the problem of recognition. Many cases of this sort were described by our observers. A few typical cases, selected from different series of the experiment, will be quoted and briefly discussed.

After his first presentation of the Bulfinch type of learning, the letter 'B' was presented to Fn. for recognition.

Fn., Bulfinch 'B,' 3.6 sec. "New. I never saw that letter. I did a great deal of thinking here. My perception of it was very clear, but I just attended to a little part of it at a time. My visual schema of five places came up, but the places in it did not seem stable; it seemed to make no difference whether they were at one spot or another. I finally tried to call up images of all the 'B's' and place each in its proper place in the schema. I found I could not get clear images of them and I gave it up. It seems absolutely new."

The schema of which *Fn.* here speaks has already been described (p. 351); and a reference to his descriptions of recognitions of Bulfinch will show the prominent part which it played in his familiarity with this type. In the experience quoted above, *Fn.*'s attention did not behave as it usually did in his encounters with known letters. First of all, instead of being directed to a characteristic feature or group of features,

[25] This intermediate stage may manifest numerous levels. The number and the constitutents of these levels seem to depend upon a multiplicity of factors, such as: individual differences, complexity of material, length of interval between exposures, etc.

he found that his attention wandered over the letter, examining it bit by bit. Next, on the appearance of his schema, instead of attending to a particular part of it as was the case when he experienced familiarity with the stimulus, he found it all confused and apparently equally unimportant in all its parts. Finally, instead of passing from percept to habitual and appropriate reactions, he was aware of much interpolated mental activity and continued strain.

One of *V.*'s experiences, in which she failed to recognize a familiar odor, is instructive. In learning the perfume called Coast Violet, she had immediately associated the odor and its name with clear visual imagery of pale violets growing on flat sand dunes,—an image directly traceable to experiences at her favorite coast resort. This was accompanied by very pleasant affective toning, and supplemented by a frequent repetition of the words 'Coast Violet' in vocal-motor imagery. Her subsequent recognitions of this odor made use of the same experiences; their number decreased rapidly, but no new activities or processes were present. Two weeks after her first learning of the odor, though she had recognized it as familiar in the meantime, she reported the following experience.

Observer *V.*, Coast Violet, 21 sec. "I think I've never smelled this before. I tried, excitedly, to place it in a former sitting,—this in a strong contraction of muscles as though to face in the direction of the room in which we sat last time. This faded out of consciousness and I leaned forward in an attempt to get more of the peculiar quality of the odor. Pleasant affective toning welled up, and vocal-motor imagery 'perfume.' Then a visual image of a bright bed of flowers,—tulips, I think. Then my attention seemed entirely taken up with an auditory image of your voice saying 'introspect.' There was no familiarity in the whole process."

Here, from the very inception of the experience, a new set of images and activities ran their course, and no 'feeling' of familiarity resulted, or, as I should prefer to put it, this experience of a new sequence of mental events *was* the experience of unfamiliarity.

Bd.'s introspections in the olfactory experiment furnish several cases of absolute non-recognition of odors which had been presented before, or even partially learned previously.

Observer *Bd.*, Coast Violet, 10 sec. "No familiarity. While I was smelling it, two or three names occurred in vocal-motor terms, but in very fleeting form: 'Violet, Rose.' They slipped right through consciousness: there was no tendency to accept one rather than another,—indeed, none seemed appropriate."

In cases where *Bd.* recognized this odor, his experience followed the same sequence which occurred in his learning experiences, *i. e.*, awareness of odor quality, organic sensation of relaxation, together with the name 'Coast Violet' in vocal-motor terms, and immediate shift of attention.

A typical description of *B.*'s recognitions of the Rigoletto selection has already been quoted (p. 340). The following is a case where this air seemed quite new and unfamiliar up to a certain point in the experience,—namely, the point at which the sequence of processes formerly experienced with this air enters consciousness.

Observer *B.*, Rigoletto, 15 sec. "It was some time before I realized that that was a familiar air. I kept trying to place it in the experiment and make it seem familiar,—this in terms of calling up former sittings in this room, imagery of you, of myself and of some auditory snatches of airs. But the whole thing was confused. I felt tense and puzzled. Then suddenly I fell into the rhythm and the air began immediately to seem familiar."

b. Confirmatory evidence. To our own cases, already quoted, may be added an exceedingly interesting case recently published by Borel (43). A French medical student of his acquaintance described to Borel two experiences of '*jamais vu*,' each of which occurred as he was walking down a street which he had traversed many times. On these two occasions, however, he was walking in a direction opposite to that usually taken. He experienced, each time, a feeling of utter unfamiliarity, though in neither case was there any strain, anxiety or unpleasantness. Borel believes that the phenomena were due to the reversal of the order in which the perceptions were experienced. He inclines to Bergson's view of recognition as an awareness of an adopted motor response (42, p. 111) and maintains that it is difficult to change the order of such responses. Therefore, he concludes, when series of perceptions are aroused in their usual order, a feeling of recognition results, but if perceptions are aroused in an unusual order, non-recognition ensues.

But non-recognition can not be dependent entirely on the order in which perceptions come to consciousness, else every one walking down a familiar street in reverse direction would repeat the experience of the French medical student. Moreover, in our own cases of non-recognition the perceptions often arrived in normal sequence, but the subsequent mental processes did not. Borel's idea of the necessity of the accustomed sequence of mental activities is in agreement with our own; but we would not confine those activities to the perceptions of the objects recognized. The sequence which our data seem

to us to establish as essential to recognition proceeds, in the most nearly mechanized cases which still have the awareness of familiarity, from *Aufgabe* to clear perception, thence to appropriate reaction, culminating in a shift of attention. Intermediate processes of associating, comparing, and the like, occur in the case of less familiar material.

This envisagement of recognition as an awareness of such a sequence of events is well suited to explain the experience of unfamiliarity reported by Severance and Washburn (69) where the observers' attention was concentrated upon a given object until its familiarity vanished. The normal sequence of mental events was not permitted to run its course.

E. False Recognitions.

During the course of these experiments, there occurred, with each observer, several cases in which 'new' stimuli were falsely recognized as 'old.' We shall quote a number of typical cases and discuss what seems to be the significant features of these paramnesias.

Observer *Fs.*, Quelques Fleurs. (New), 2.4 sec. "That's violet. Almost instantly I was aware that that was a fragrant odor. My attention singled out the unmistakable violet character. The vocal-motor image 'vi' occurred and then I withdrew the bottle and said 'That's violet.'"

Fs. gave every evidence here of being certain of her identification. The odor seemed entirely familiar, though it was, as a matter of fact, quite new to her. Soon afterwards she learned to recognize this odor easily and unfailingly; and on a later occasion she stated that the odor was not at all like violet in quality and unlike any other she had ever smelled. Her whole procedure, however, in the experience quoted above, was identical with that characterizing her usual experience with the violet odor. It consisted in a preparedness to recognize (evinced in a tense attitude and an expectant expression) and a clear presence in consciousness of a perfume quality, followed by the uninhibited vocal-motor image of a known perfume's name, which was then actually spoken aloud with conviction.

Observer *F.*, Hansel and Gretel. (New), 20 sec. "At first I thought it was going to be familiar. I began humming along with it and 'Meyerbeer's Prophet' came to mind in auditory imagery. But instead of accepting this, I found myself repeating it with a questioning accent. My humming had ceased, my tension increased, and all the familiarity was gone."

Here again, we find the experience of familiarity to be an habitual behavior of attention. *F.* finds that he has been

experiencing all the events which usually compose his total reaction to a known air, and the air seems familiar. But when, instead of experiencing the usual reaction and then turning from the experience to attend to something else, he finds his attention lingering on it, repeating part of it, hesitatingly, then all sense of familiarity departs.

Fs. had a similar experience on hearing, for the first time, the selection from Humperdinck's opera.

Observer *Fs.*, Hansel and Gretel. (New), 30 sec. "I was sure that was a familiar one at first. I really recognized it as Loch Lomond. The experience was like this. I was prepared for an old air,—this in terms of adaptation for listening, with my hand poised above the reaction-key. When the music began, I started to hum. My vocal apparatus formed itself to say 'Loch' and I felt my finger innervated to give the tap. But the movement was inhibited, apparently through the shift of my attention to the characteristics of the music again. The air grew very clear and insistent; I ceased humming and became very tense. Now I was very actively noting the music and experiencing recalls of other bits you have played to me here. No name for this came up, and I finally gave you the signal-tap. I'm still keyed up over that. What in the world is it?"

In the first part of this experience is a typical example of false recognition. The auditory stimulus, flooding into a consciousness dominated by a recognition-*Aufgabe*, was at first followed by the course of mental events characteristic of the experience of familiarity: the singling out of a feature to be noted; bodily adjustment to the stimulus, which took the form of voiceless humming; partially imaged pronunciation of a name; and an initiated reaction on the signal key. The sequence was identical with that present in correct recognition.

The experiments with the New York Point alphabet furnished several instances of false recognition. *W.* describes an experience in which 'i,' which he had never before examined, was recognized as 'a,' which was very familiar to him.

Observer *W.*, New York Point 'i.' (New), 5 sec. "As soon as I perceived that there were two dots, the tactual impression became non-focal, and I attended only to a very clear visual image of the dots; their vertical position seemed very prominent. With the appearance of that visual image, there was a very definite feeling of familiarity; no memory images accompanied it,—the familiarity seemed rather to be in my clear perception of the symbol itself. I took my fingers off the dots and said, 'That's "a."'"

W.'s criterion for recognizing the 'a' symbol (which consists of two horizontal burrs), was a visual image of two dots. He always reported that he first had an awareness that there were *two* dots, and then a consciousness of the direction in

which they lay. On being presented for the first time with the 'i' symbol, which consists of two burrs arranged one above the other, his clear visual image of the two dots, an awareness of direction succeeded by the usual reaction to these cues, constituted entire familiarity which culminated in the pronouncing of the name 'a.' Had the awareness of the particular direction been prominent enough in consciousness to inhibit the usual reaction to the 'a' stimulus, the entire color of the consciousness would doubtless have been changed, and uncertainty, if not an actual experience of unfamiliarity would have resulted. Cases of non-recognition of old stimuli present pictures of just such occurrences (pp. 375ff.).

Examples could be multiplied. The significance of these cases of paramnesia is that the mental experience involved in each experience is one which moves in a sequence identical with that present in cases of correct recognition: the same significant detail or details are noted; the same associations (if any) are aroused; the same bodily reaction follows after a perceptible time; the same shift of attention to other matters completes the experience.

Such an interpretation of the phenomena of '*déjà vu*' would seem to explain it better than does that of Lalande (67) who assumes that cases of this sort occur with stimuli of which there really has been a double perception, the first being unconscious; when the two become integrated a feeling of familiarity subsequently arises. This account of 'false recognition' really explains it out of existence. There are doubtless many cases of apparently false recognition which could be accounted for in some such way. But many others do not seem to admit of such an explanation. The cases quoted from our own experiments can not be so explained, for our experimental conditions and our introspective evidence rule out the possibility of such a double perception.

Bourdon (15) points out that it is exceedingly difficult to find a case of a wholly new experience in the consciousness of the adult; and he holds that in all cases of '*déjà vu,*' the stimulus which is recognized resembles one which was formerly experienced. He explains this by invoking a 'feeling of familiarity' (due to facilitation of perception) which attaches to the recognized object. But we may accept Bourdon's hypothesis without agreeing with his explanation. Even if all stimuli which seem familiar do resemble others which have belonged to the observer's experience, the important fact remains, that the mental events attending the recognition of these stimuli form a sequence identical with that which char-

acterizes the recognitive experience for stimuli of that modality.

3. *Conclusion*

Our investigation has shown that the experience of familiarity is essentially a motile, flowing consciousness,—the product of a peculiar sequence of clearnesses, durations and adjustments. The apparently simple experience of recognition proves to be a complex process whose degree of complexity varies with the degree of familiarity of the stimulus.

Various levels of recognitive experience may be differentiated: An '*initial*' level where the stimulus is but slightly familiar and where the (incipient) recognition is a peculiarly haunting and persistent experience. This level is characterized by a wealth of sensory components and by a keenly active attention, attention usually being busied with searching for a name or for other associations which 'fit' the situation; the consciousness of 'fitness' is essentially a behavior of attention,—when the 'fitting' association appears the search is abandoned and attention shifts elsewhere. The '*intermediate*' level differs from the initial level in that it is briefer and much less rich in sensory content. In the '*final*' stage the process is very much syncopated; imagery is often wholly lacking here, an appropriate reaction frequently ensuing upon the perception of the stimulus.

Imagery plays a progressively less important rôle during the life history of a complete familiarization; affective processes and the consciousness of self appear so irregularly that they are to be regarded as entirely fortuitous.

There is a functional component, however, which is constant throughout the various levels; and one is impelled to conclude that it constitutes the essence of the recognitive experience. This functional complex consists in an on-going consciousness of activities, of pauses, of adjustments and shifts of attention. In other words, recognition is a sequential experience which, although highly unified for consciousness, may be analyzed into components; and its *sine qua non* is an orderly procession of mental events,—from clear percept through appropriate reaction to attention-shift,—under the direction of the *Aufgabe* or the *Einstellung* to recognize.

IV. Appendix

A. A Brief Summary of Theories

The theories which have been advanced to explain the nature of the process of recognition fall into two groups, which may be called

theories of underived and theories of derived awareness. In the bibliography which is appended, representative writers on recognition are classified according to the viewpoint which the present author understands them to champion. Theories of the former type describe the consciousness of 'known,'—one's awareness that a given experience is not new,—as a mental datum which is immediately given; this datum is conceived to be a quality which is an inherent part of the perception of a repeated stimulus, irreducible and incapable of further description. Within this type of theory one finds two subtypes,—the 'intellectual' and the 'affective.' The exponents of the former view envisage the consciousness of 'known' as a purely intellectual, non-emotional datum, while for the exponents of the latter view it is dominantly or exclusively affective.

An interesting theory of the underived type is that championed by Washburn (5), who considers the feeling of familiarity to be the psychical accompaniment of the weak excitation of groups of cerebral neurones, whose activity was associated with that of the group excited by the familiar stimulus when it was formerly experienced. If these associated groups are strongly excited, so that images are aroused, she believes that perception and not recognition ensues. But is the recognized object then not perceived? And must an experience of familiarity precede every perception? The fact that the arousal of many associated images does not destroy but often actually intensifies the awareness of familiarity tells against this theory.

The advocates of the affective theory of 'derived awareness' maintain that recognition is an experience which is primarily emotional, a genuine 'feeling' of familiarity which attaches to the perception of known objects. Introspectionists maintain that an appeal to the known results of psychological analyses made in numerous studies suffices to overthrow all *sui generis* theories of recognition,—the 'feeling' of familiarity is analyzable.

The second group embraces those theories which conceive the consciousness of familiarity to be derived from certain elementary processes, sensory or affective, or both. These theories, like those of the *sui generis* or 'underived' group, may be divided into two sub-groups according to the emphasis placed by their sponsors upon the intellectual or upon the affective elements involved. At least six well-differentiated types of theory can be distinguished within the intellectual group of these theories. They may be characterized briefly as follows:

1. The *facilitation* theory assumes that recognition is due to the augmented ease with which a recurrent content comes to consciousness. This theory is usually furnished with an alleged physiological basis, the assumption being that, in consequence of practice, cerebral activity becomes more easily excitable and brain paths become more readily conductive.

Two objections may be urged against the facilitation theory. First, it helps us not at all on the side of consciousness. While it seems probable that brain processes are facilitated as they are repeated, we are chiefly interested in determining what is present to consciousness during the various stages of this habituation. Second, the most facile processes,—the processes which accompany those daily, habitual experiences to which our reactions are all but automatized,—do not bring with them the peculiar experience of familiarity.

2. The *association* theory makes recognition depend upon the arousal of images which on a former occasion have been associated with the

object recognized.[26] There are two well-marked types of association theory: *a.* the *comparison* theory, which supposes that when a stimulus is recognized, a comparison, conscious or unconscious, has taken place between the perception and revived imagery of former experience; *b.* the *fusion* theory, which bases recognition on an amalgamation of a present percept with a simultaneously aroused image of like nature. The *fusion* theory finds a variant in Semon's assumption (38) that the perception of any known object arouses a memorial trace of its former impression, the perception meanwhile having its own intensity peculiarly augmented thereby.

In criticism of the association theory, one may appeal to our experimental results, which furnish hundreds of instances of recognitions in which no associated imagery was aroused. The 'fusion' variant of this theory is more difficult to ignore, since it does not require that the aroused imagery shall become conscious. We should prefer to regard an unconscious process as a physiological one; nor can we see how such a concept of 'fusion' aids in the description of the *consciousness* of familiarity. The fusion theory, moreover, seems inadequate to account for experiences of false recognition, in which case there is no residuum of an identical past experience to be incited to arousal.

3. The *evocation* theory rests on the assumption of separate brain centers for receiving and for storing peripherally aroused impressions, and on the further assumption that recognition depends upon excitations which are centrally, rather than peripherally aroused. Certain advocates[27] of this theory refer psychic blindness to the absence of such centrifugal excitations.

The evocation theory, like that of facilitation, is of no aid in envisaging the conscious components of recognition. Even if one should accept the theory of separate centers as an explanation of the brain processes involved, one may urge against it the two-fold objection, that central excitations of associated centers must be a constant phenomenon of waking life, yet we are not continuously in the flush of familiarity; and that such excitations should be most numerous and intensive (through facilitation) in the case of objects which we hourly encounter. Yet it is not with these objects that we experience intensively the unique consciousness which is commonly called the feeling of familiarity.

4. The *adjustment* theory explains recognition as an awareness of a bodily attitude which is appropriate to an organized motor response. This theory is more nearly in accord with our findings than any one of those previously discussed; but it is not, we believe, entirely adequate. As Katzaroff has pointed out, motor responses become well organized only by habit; and it is just in cases of habitual stimuli that the experience of familiarity is lacking (55, p. 18). Motor adjustment is rather the climax of the experience of familiarity,—an essential component of recognizing; it is not the complete sum-total of the familiarity consciousness.

5. The *relation* theory attributes the 'feeling of known' to an awareness of relation. This awareness of relation is conceived to be a unique mental datum,—a datum which is a product of past experience, and which is dominantly of an intellectual sort. Calkins (46,

[26] This theory is more fully discussed in connection with the Lehmann-Höffding controversy (pp. 314f.).

[27] *Cf.* Munk (39) and Wilbrand (41).

pp. 130, 131) believes that it consists in an awareness of relation between the object of recognition and the consciousness of 'self' as persistent. Neither our experimental findings nor the writer's own introspections support the view of an 'awareness of self as persistent,' nor was such an awareness an essential component of the recognitions described by our observers. If we understand Ach (45, p. 263) his experience of 'relation' is an intellectual datum, not further reducible, containing neither sensory nor affective elements. Our recognitions sometimes contained affective components and they always included sensory elements.

6. *Mental Attitudes.* This type of theory attributes the process of recognizing to the peculiar mental adjustment which accompanies the perception of a known stimulus. Betz' (47) phrase, the 'adjustment (*Einstellung*) which goes best' seems, however, rather to be an attempt to describe the mental experience at the moment when a sense of familiarity has culminated in an identification. Clarke (48) believes that recognition is a conscious attitude, but maintains, on the basis of experimental evidence, that it can be resolved into various elements, sensory and affective.

The terms attitude and *Einstellung* seem to refer to a given moment of consciousness,—a relatively static experience. We are convinced that recognition,—and its unique and essential component, the awareness of familiarity,—is an experience whose essence consists in the fact that it is in motion, that it is extended in time, and that it consists in habitual sequences of attention.

Two groups of theories may be distinguished among those which we have called the affective theories of the 'derived' group. One of these emphasizes the consciousness of self as a basic component of the 'feeling of familiarity,' while the other regards the act of recognition as a unique affective quality which has come to be attached to the re-experiencing of any mental process. If our data have yielded conclusions which are applicable to all recognitions, neither of these theories has any factual basis.

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CERTAIN SOCIAL ASPECTS OF INVENTION

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In studying the conditions under which inventions appear, perhaps three things most impress one: (1) the lack of any regular relation between the value of the invention to society and the degree of ability involved in making it; (2) the similarities in the motives of the inventors; (3) the wide differences in their training and their methods of attack and of work.

1. The social value of an invention shows little with regard to the genius required for it. There can be little question, for instance, that Watt's work with the complicated details of the steam engine involved not only greater technical knowledge of the laws of steam, iron, steel, etc., but also more complicated inductive and imaginative processes than such an invention as Gutenberg's of movable types. Movable types were only the last stage of a social process that had been going on for 250 years. As early as 1190 a German mill had been making paper out of linen rags, thus providing a much cheaper material than parchment for writing and engraving. This naturally gave a great stimulus to the reproduction of manuscripts, and in many instances plates were engraved of the entire page of a manuscript and as many copies made as desired. What Gutenberg did, therefore, in 1438, was to form the idea of engraving the single letters instead of the entire page, and of holding them together in some kind of frame while the print was being made. It seems a small thing to bring about the marvelous changes which followed, and we do not know whether Gutenberg himself foresaw its wider effects on civilization, though probably he did realize its immediate value in simplifying the labor involved in printing. It takes far less skill to engrave a single letter than to engrave a page of words, nor would it take long to learn the twenty-six letters of the alphabet, whether for the purpose of engraving them or of setting up copy. In spite of the relatively small amount of originality involved here, no one would question that the printing press has done at least as much for civilization as the stationary engine.

In this connection we think naturally also of the many instances of men who have made inventions and discoveries already made by others. There is no doubt that the spinner Hargreaves invented a spinning jenny in 1764 which spun twenty threads at once. He had as much inventive genius as Arkwright, if indeed he had not more, but he lacked the social outlook. The same holds of the sewing machine. The Frenchman Thimonnier not only invented but patented a sewing machine in France in 1830, before Howe had even begun to think of it, but the mob prejudice which threatened his life on account of it caused it to drop out of use and almost out of memory. In our own country Walter Hunt invented another sewing machine at least six years before Howe did, and sold his right in it to a Mr. Arrowsmith, but neither of them saw the social possibilities, a patent was not even applied for, and the model was relegated to the garret until Howe's success recalled this earlier invention to mind. We know that Bell has become rich and famous for inventing the telephone because his application for patent rights reached the patent office in Washington some twenty-four hours sooner than Gray's did.

Of such and many similar cases it is as trite to say that the unsuccessful man had as much ability as the successful, as it is superficial to depreciate the genius of the successful man because others have done the same thing. The interesting and important problem both for the psychologist and the sociologist is to ascertain if possible what other factors, whether individual or social, are involved which lead to the final success or failure, and how the waste of duplicating work can be avoided in the future. A knowledge of the lives of inventors and the conditions under which they lived should be at least suggestive, although it must be admittedly more or less defective in the details.

One group of inventions which shows the constant interaction between the individual inventors and social conditions is that concerned with making clothes, including the spinning jenny, cotton gin, power loom and sewing machine. If there were time and space doubtless we could carry these back to the dawn of civilization, but we will begin rather arbitrarily with Kay's invention of the flying shuttle in 1733. Before this a sort of equilibrium had been reached between the weaving and spinning processes. One spinner could hardly supply enough thread to keep one weaver busy, but this made the price of thread high enough to encourage spinners and discourage weavers, so that spinners increased enough in num-

bers to supply at least a fair amount to the weavers. Then came Kay and upset all this by his shuttle, which would send the thread through a warp of any width and do it twice as rapidly as before. The inevitable result followed. The weavers could do twice as much work, and wanted twice as much thread, but the spinners could not supply the thread for two reasons. In the first place they were working as fast as they could before, and in the second place, not many additional spinners could go to work because it was difficult to get more raw cotton. As a result the price of thread increased greatly, and the weavers were obliged to be idle one-half or one-third of their time. It is estimated that in 1760 in Lancashire, England, there were some 50,000 spinners and as many weavers as could find thread for their looms, but the looms stood idle much of the time, the price of thread remained high, and the need of relief was great.

Arkwright saw the need and, barber though he was, set about satisfying it in order thereby to make his own fortune. He was not the first to try to spin by machine, nor was he himself a machinist. Indeed we can not even affirm positively that he was ignorant of Wyatt's invention of 1733 or of Hargreaves' jenny of 1764. We are not even sure how much is owing to the machinist Kay whom he engaged to make his models for him. The most characteristic thing in his life is his clear realization of the need of more cotton thread and the gain to the man who could supply that need. In the invention itself, the most difficult part was to draw the cotton out to a thread by machine. Arkwright tells us that he finally got his idea from seeing red hot iron drawn out between two pairs of rollers, of which one pair revolved more rapidly than the other. So if cotton is put between rollers, the second pair revolving more rapidly than the first pulls it out into numerous threads. This was the central feature of the invention, though many details were added, to avoid breaking the threads, to twist them, to wind them onto spools, and so on. All this took up six years, from 1763 to 1769, in which Arkwright had spent all his money, had nearly starved himself and his wife (who finally left him), and had incurred the popular suspicion of being in league with the devil. In 1769 he took out his first patent and in 1775 a second on an improved model, but the jenny did not come into general use at once because he incurred the hostility both of the spinners and weavers. The spinners burned his mills when they could, because they believed that his invention would deprive them of work, and the cloth-makers organ-

ized against him and agreed not to buy his thread, because they thought he was making exorbitant profits. The long years of suit for infringements of his patent rights ended in 1784 by making the invention free, and the importation of raw cotton into England took a tremendous leap, rising between 1785 and 1790 from about 5,000,000 lbs. per annum to 25,000,000.

It is most interesting to notice however, that practically none of this came from our own southern states. In 1793, our total exports were only 187,000 lbs., and there was no prospect of an increase because we could for the most part only raise the short stapled cotton, which was very difficult to separate from its seeds. A smart negro woman could pick out one pound of cotton a day from the seeds, and would then have six pounds of seeds to the pound of fibre. Arkwright's spinning jenny therefore received checks in two directions and put the pressure on strongly in two places. It was limited by the amount of raw cotton which could be procured, and also by the rapidity with which the thread could be woven into cloth.

Let us shift the scene accordingly to Mrs. Nathanael Greene's Georgia plantation in the years just after the Revolution. At the end of the war our government was so poor that it paid the soldiers for the most part in grants of the new land west of the Appalachians and thus started the stream of migration which drained the eastern coast for years. Georgia, in common with the other southern states was losing its men, and it could offer no counter attractions strong enough to keep them at home. At that time the chief southern products were tobacco, rice, and indigo, and there were vast tracts which were not adapted to any of these, though they were suitable for the short stapled cotton. By 1790 the greatly increased English demand for raw cotton was widely known, but to southern patriots there seemed no prospect of our country benefiting by it because the short stapled cotton was so entangled with its seeds. This aggravating condition was the subject of much thought. It was under discussion at Mrs. Greene's one day by a party of gentlemen, who brought up the question of whether a machine could not be made that would separate the seeds from the cotton. Mrs. Greene exclaimed that if such a thing was possible she knew the man to do it, and she introduced Eli Whitney, a young Yale graduate who was tutoring her children to support himself while he studied law. Her enthusiasm was due to the fact that Eli was constantly mending and making things about the

plantation, some of them pieces of work requiring fine manipulation. He had grown up in a machine shop and was noted wherever he went as very skillful with his hands. Whitney had a long talk with these gentlemen about the profit to the South from such an invention, as well as to the inventor, and was so impressed by it that he got some unpicked cotton and began to experiment with it. He had to make various tools for himself, but in only a few months he had the central idea of the cotton gin in rough working order. The cotton was laid on an iron grating, something like a window screen but much coarser. Below this grating was a cylinder or roller set with projecting teeth in rows, like a coarse saw. When the roller was turned the teeth came through the holes in the grating, seized the cotton and tore it off from the seeds and down through the holes, the holes of course being smaller than the seeds. Whitney tried wooden points first, but found that they broke, and then the saw-like arrangement, but this was also defective and for some time he was puzzled, till one of the children brought him some stiff wire one day to make a bird cage, and he thought it was stiff enough to make teeth for the gin. When he first used this it worked so well that he called Mrs. Greene and others to see the triumph, but after a few revolutions the cylinder became so clogged with cotton that no more was torn off from above. Then, the story goes, Mrs. Greene seized a broom lying near and held it firmly against the roller as it turned, so that the cotton was brushed off, thus completing the invention. Whitney made this a permanent part by putting in a second roller covered with brushes, which revolved in front of the first and cleaned it as it filled with the cotton. This was the first cotton gin. It ran by hand, but it cleaned fifty pounds of cotton a day instead of one. Within a short time, however, Whitney enlarged it to be run by two horses, and to clean 500 lbs. a day, and later on it was run by water or steam power on a still larger scale.

The news of the wonderful invention spread far and wide. It went into use so rapidly that while in 1793 only 187,000 lbs. of cotton were exported, 1,600,000 were exported in 1794, a year later, 6,276,000 and in 1803, only ten years later, 40,000,000. Here, too, the inventor at once became involved in disputes over his patent. Many men succeeded in stealing the plans of the gin and making it for their own use. Whitney's factory was burned, and his patent right was defectively worded so that it was easy to evade. He could not even get witnesses to testify that his gin was in use in

Georgia, though in one case three were in operation so near the courthouse that the noise could be heard there distinctly. He brought suit after suit, nevertheless, spending there what money he received from other states, and finally after thirteen years of litigation he obtained a favorable decision, but was not able to get an extension of his patent right for a second term. Whitney himself therefore never made much money from his invention, and yet the judge who rendered the final decision said that the cotton gin had paid the debts of the South and trebled the value of her land. Surely this was a remarkable effect to come from four or five months of work.

Let us turn back now to the other check upon Arkwright's spinning jenny, that is, the inability of the weavers to use all the thread that could be spun. When the final decision was reached against Arkwright's patent letters, so that anyone could use the spinning jenny without paying for it, it became a burning question among business men whether to put up thread factories or not. A party who were dining together were discussing this one day in 1784, and reached the conclusion that thread factories would be risky investments, because weavers could use only a small part of the thread that could now be made. The clergyman of the town, Dr. Cartwright, who happened to be with the party, remarked that the only thing that would be satisfactory to every one concerned would be for Arkwright to invent a weaving machine that could go fast enough to use up all his yarn. This was very amusing to the manufacturers, who demonstrated to their own satisfaction how impossible it would be for a machine to make the movements necessary, in answer to which Dr. Cartwright could say nothing but that if a machine could play chess, like the one then on exhibition in London, another machine could certainly weave, which was a much simpler operation.

This conversation left such an impression on Dr. Cartwright's mind that he determined to try his hand at making such a machine, though it would have been hard to find anyone less fitted than he for such work. In the first place he came from a gentleman's family, in which work with the hands was considered degrading, and in boyhood he had never shown any liking for tools. In the second place, he had already acquired considerable reputation as a poet and writer, and had clearly before him affluence and reputation in those lines.

So ignorant was he of weaving that he had never seen a

loom in operation, nor did he desire to see one, but set to work *de novo*. He became more interested as he went on, engaged a mechanic to work out his ideas, and in the course of a year had a loom which he thought wonderful. He proceeded to take out a patent on it, and found to his intense mortification that his loom was not nearly so good as those already in use. Then he condescended to study what others had done, and set to work again. This time he worked for two years, and in 1787 he patented a loom in which the picking, shedding and beating up, formerly needing the hand, were done by machinery. This went considerably faster than other looms, though it needed one weaver to each loom, but its great defect was that if a thread broke the loom could not be stopped quickly, and so the cloth was likely to have holes and bunches. Cartwright worked in vain to remedy this, and not until 1841 was a device made by another man that was successful. Up to that time the hand loom competed with the power loom with considerable success, because its cloth was so much better in quality. About the time that Cartwright took out his second patent, other men took out a patent on a method of sizing, or stiffening the warp before it was put onto the loom. This made Cartwright's invention far more practical, because the warp was easier to handle and less likely to break. With this addition a child of fourteen could run two looms and weave three and a half times as fast as the hand weaver.

Cartwright met the same opposition as Arkwright. His mills too were burned by mobs, and his patents were infringed. He spent all his money in the invention, and finally went into bankruptcy and had to start life anew in his old age. In his case however, the Lancashire cloth manufacturers petitioned the Lords of the Treasury to reward him for his public services, and they gave him £10,000, which freed him from financial worries. His mind seems to have literally rioted in inventions in his later years, many of them useful ones, and it is interesting to know that he was one of the men who gave the most encouragement to Robert Fulton.

These three inventions therefore made cotton cloth cheaper than it had ever been in the history of the world, but the social pressure was only shifted to another place, viz., to the making of it into clothing. The abundance and cheapness of cloth naturally made everyone desirous of more clothing, but the amount of clothing was strictly limited by the rapidity with which sewing could be done by hand. The pressure was

felt in every kind of clothing but perhaps especially in the difficulty governments had in equipping their armies properly, both with clothing and with tents. In the seventy-five years preceding Howe's sewing machine patent of 1846, various patents had been taken out in France, England and our own country, for embroidering, quilting and knitting by machine, and we have already referred to Thimonnier's patent of 1830.

There is no evidence that Howe knew of Thimonnier's invention. He seems to have got his inspiration from a conversation which he overheard between his employer, a mechanician, and some men who had come to get his help in contriving a knitting machine. Mr. Davis examined their model but asked them why they bothered with a knitting machine when a sewing machine would be so much more profitable. They said that it would not be possible to make a sewing machine; to which he retorted that he could do it himself without half trying. The men told him he would become both rich and famous if he did, but apparently he did not care to, nor did Howe for several years, though he did think about the possibility of it. He was then a boy of 18 or 19, poor and sickly. When 21 he married, and both his sickliness and poverty increased steadily, so that he was incompetent in his work and wretched. In very desperation to relieve his poverty he began in 1843 to experiment seriously on a model for a sewing machine. At first he assumed that the needle in the machine must make much the same movements as when held in the hand, and he seems to have spent something like a year in fruitless attempts to imitate the hand movement, although he did alter the needle, experimenting with a needle that had two points and the eye in the middle, and trying to invent a device that would push the needle back and forth through the cloth. At length he asked himself why he should try to get a stitch like the hand stitch? The necessary thing was only to hold the two pieces of cloth together firmly. After he had thus freed himself from too close imitation he progressed rapidly, so that in a few months he had the idea of the lock-stitch worked out on his rough model. In the lock stitch the eye of the needle is as close as possible to the point, so that when the point is pushed through the cloth the thread is carried through and makes a loop on the lower side. A shuttle carrying thread is then thrown through this loop, the loop is drawn tight and the first stitch is made complete.

This first wood and wire machine however, was far from being good enough to convince others of its commercial value,

but Howe was so sure of ultimate success that he gave up his position and took his family to live first with his father and then with Mr. George Fisher, who believed in the machine enough to become his partner, and who was willing therefore to support Howe's family and advance him money. About six months later his model was good enough so that he sewed his first seam on the machine, and a few weeks later, in May of 1845, he sewed two suits of clothes on it, one for his partner and the other for himself. This first model was a very little thing that would fit into a box with a cubic capacity of only one and one-half feet. It was turned by hand, but it sewed 250 stitches a minute, about seven times as fast as the most rapid seamstress, and we all know how much firmer the machine stitch is than the hand stitch.

Howe tried in vain to get a tailor to exhibit the machine in Boston but finally did it himself, sewing anything brought to him and racing with any tailors or seamstresses who were willing to do so. Still no orders for the machine came in. One reason for this was that it cost $300, a price so high that it could only be used in large tailoring establishments, but other reasons were the belief that it could only sew straight seams, and that it would deprive tailors and seamstresses of work. In September, 1846, he took out the patent on his machine, and for another year struggled on against indifference and ever increasing poverty. Then as a last desperate venture his father bought a steerage ticket to London for Elias's brother Amasa, in order that he might try to interest some wealthy man there. Amasa succeeded in rousing the interest, but unfortunately the corset-maker in question was willing to take advantage of his dire poverty and his inexperience, and for £250 he bought the right to take out the English patent, to own the model Amasa had brought with him, and to make and sell as many as he pleased. He agreed to pay Elias £3 on every machine sold in England but never did so, though he made for himself a fortune of over $1,000,000. Then he persuaded Elias to come over in order to adapt the machine to corset-making, but after he, with his wife and three children was settled in London, there was constant fault-finding and finally a break. Elias was discharged and left practically penniless in a strange land. The family nearly starved to death literally, and at length Howe borrowed money to send them home in the steerage, while he stayed on to finish his third model. His own situation became more desperate all the time, however, and at length only by pawning his patent letters was he able to get money

to buy himself another steerage ticket to New York. He landed in this country with twenty cents, and his biographers tell us, as weak from lack of food as if he had had a severe illness. Within a week he received news that his wife was dying in Cambridge, but he was unable to go until his father sent him enough money to pay for his ticket, and in order to attend her funeral he had to borrow a suit of clothes.

Now, as with other inventors, he found that the sewing machine was coming into favor in this country. Other men had also made machines, and though there is little evidence that they copied from Howe, they did in most cases infringe his patent. He tried at first to negotiate with them privately, after recovering his patent letters from the pawnshop by means of borrowed money, but under the leadership of Isaac Singer they refused to treat with him, and he either had to bring suit or lose all benefit from the invention. His father again came to his aid, mortgaging his farm this time, for $2,000. In the course of three years the matter was decisively settled in Howe's favor, and when his first patent expired he was able to renew it for an additional seven years, so that at its expiration the machine had earned for him about $1,700,000.

The modifications of the machine are almost infinite. Between 1842 and 1895, patents to the number of 7,430 were taken out on various accessories. It is used not only for sewing cloth, but also shoes, harness, corsets, rubber hose, belting, etc. It is now run usually by steam, and instead of 250 stitches per minutes can sew 900. In some instances a considerable number of needles (two to twelve) is fastened to one machine so that several seams can be sewed at once.

These four inventors show in a very interesting fashion the possible individual variations in invention, together with the interdependence of inventions and general social conditions, and the combination of motives which influence each individual. All four had a strong conviction of the social value of their inventions but the other personal factors were very different. Arkwright saw the future of the spinning jenny, and the wealth to be realized from it, but the extent of his mechanical genius is a question. He had instead the power of choosing and controlling men, which not only procured for him the first use of the invention but later on enabled him to organize his factories so well as to become wealthy in spite of the loss of his lawsuits. From the available data one is inclined to think that he was far more the able administrator than the inventive genius. The spirit of

two men could hardly vary more than did his and Cartwright's. The latter's chief, if not sole motive, was to demonstrate the possibilities in a machine, although he realized also what its value would be to society. He had, however, no such personal ambition as Arkwright, and was more likely to lose in social position as well as wealth than to gain by going into such mechanical work. It is difficult to understand just why he should have taken up the task of making a loom with such ardor, when he had never before shown any aptitude for tools, but the outcome seems to show beyond doubt that he had very unusual inventive genius. His first crude loom is itself a remarkable achievement for a man who had never seen one, and the variety of his other inventions, many of which he gave freely to other men instead of patenting them himself, shows his breadth of imagination. In Whitney and Howe, on the other hand, especially Whitney, we get men who grew up in the machine shop, but while Whitney had a great deal of administrative ability, Howe was so hampered by his feeble health with its consequences of inefficiency and self distrust that it was difficult for him to convince others of the value of his invention. It would be very interesting to see how far these men conform to Adler's theory of organic *Minderwertigkeit*, but it can not be attempted here. All save Cartwright assuredly had the sense of poverty and social inferiority, while Howe had in addition a very weakly constitution.

Another chapter that would be well worth while psychologically would be a study of the motives that led manufacturers to the attempts to infringe the patents on the one side, and the obstinacy of all four of these inventors in fighting such infringements on the other side. This however might well be extended to all inventions. So notorious is such infringement that we are told (in a recent number of "Science") that Edward Weston protected himself by not taking out a patent on a given device until he had an improvement on it so far along that he could take out a patent on that also within a short time, and thus balk the numerous manufacturers who always take advantage of the description required in the application for a patent. Manufacturers on the other hand, are so well aware of the possibilities of stealing inventions, that if one of their men invents a device they often prefer not to take out a patent but to have the machines made secretly in their own factory and keep them under lock and key, paying the men who use them liberally enough to secure their loyalty. Nor do they scruple to send their own employes

into the factories of others to pick up what they can in the way of new devices. It is not uncommon for them to make a contract which gives them the right to all of a man's inventions for a term of years.

It is not difficult to understand the feelings on both sides in the matter. The inventor naturally enough feels that he himself has created the machine, and has the first right to whatever it can earn. In some cases, as with Howe and Morse, who underwent great privations in the course of their work, most of us must feel that no amount of money can be an adequate compensation. The inventor who has had to endure for years the distrust and criticism of friends and perhaps of his own family, to say nothing of poverty, naturally feels that he has a right later on to any kind of compensation he can get, although nothing can really heal the wounds made by the ridicule and scorn of his social world.

On the other hand the manufacturers have considerable reason for feeling that it is more or less accidental that this or that individual was the first to make or at least the first to *patent* a given machine or device, and that the rewards for the invention are often all out of proportion to the work and talent involved. Whitney, e. g., worked only a few months on the gin and spent very little money, but in introducing the gin through the South he took one pound out of every three cleaned by way of payment. In the contract made with the state of North Carolina it agreed to pay him two shillings and six pence a year for every saw used in the state. That is, Whitney would not sell a single machine, but would only allow the use of them under strict conditions of supervision, which irritated the planters and inclined them to take any possible advantage of him. Not only that, but the planters were poor men as a rule, and probably felt that their need was made the occasion for extortion.

Again, in Whitney's case no one could question that he had made the invention, but in Arkwright's the fact that he was unable to make his own models almost inevitably throws doubt on his inventive ability. In the actual process of invention the relation between manipulation and originality is so close, the chance of an accidental, unforeseen success or failure in combining the various parts of the machine or the various materials used is so great, that it is small wonder Arkwright's competitors questioned whether he or his machinist or Hargreaves should have the credit. Again, we have shown repeatedly that various men have made the same invention, or that the final step to be taken was a very small one.

Howe simply happened to be fortunate in taking out the first American patent, as did Bell. Everyone knows that Wallace formulated the same theory as to the origin of species as did Darwin, and that both got the germ of their idea from Malthus. The one factor in each case which gives one man sufficient advantage over others so that he gets most of the fame and the money for the invention seems more often than not to be entirely unrelated to the genius or talent necessary. In Arkwright's case it was his rather bullying disposition and his administrative ability, though his patent letters were so defective that he finally lost his lawsuits. In Howe's, on the other hand, it was solely due to the fact that he took out his patent as soon as possible, while he seems to have been totally lacking in the ability to impress and manage men so conspicuous in his most prominent opponent, Isaac Singer. Whitney finally made his fortune in the totally different line of gun-making, after spending most of the money that came in from the gin in lawsuits; while Cartwright again, after similarly spending his fortune on lawsuits lived on a government pension and gave away many of the later devices which might have made him wealthy. These men seem to have secured recognition and to have been motivated by their sense of the social value of the invention, though this was not sufficient to secure wealth to all of them.

But again, if we had access to the inner history of factories, there is no doubt that we should find that many workmen make devices or inventions which have far-reaching effects on the industry without themselves foreseeing the effects. The short cut appears in the course of working with the machine, and the workman may use it himself for weeks or months before the foreman or manufacturer notices it. Then only too frequently the manufacturer adopts the device either without giving the workman any credit or money payment, or giving him a sum very small in proportion to the saving of money or labor made by the device. So we have on the one side factories offering rewards of small sums for inventions, and on the other side workmen refusing to think or plan, or concealing their improved methods, or when they are shrewd enough carrying them to a competing firm to sell.

It would appear therefore, that while the actual attainment of fame and fortune depends upon the social insight of the inventor impelling him to take out patents, and while in many instances the value to society and the desire to improve his own position and fortune are the motivating factors, the mechanical ability or inventive process itself goes on in many

other cases without any apparent relation to society, but more as a by-product of the interaction between the workman and his machine.

Rignano in his lucid series of articles has restated the point made by several others that scientific generalization rests in the end upon the possibility of repeating the experiments on which the theory rests, that is, in repeating the sensations and perceptions, so that all normal persons may get the same experience. In proportion as we depart from experiment and proceed to inference and induction we enter debatable ground, for it is increasingly difficult to keep clearly in mind all the data and particulars involved. Nevertheless, the history of science, and especially of mathematical science, which Rignano discusses in his latest article, shows that even the most abstract ideas, imaginary numbers, and the like, though they may be symbols of symbols, run back to a physical reality, to a perceptual experience, including in this the kinesthetic factors and particularly those involved in manipulation.

Granted such a basis of sensation and perception, the part which they play in any creative thought process becomes a highly important problem. To what degree can a man carry on synthetic thought without recourse to perception? What part is played by the process of writing or speaking as contributing perceptual factors? Is the new combination more likely to be attained first in thought or in a seemingly accidental combination of perceptions? In invention we see as clearly as anywhere else, perhaps, the close relation between the perceptual experience and the concept or theory or abstract truth, but also the wide variations possible in the proportions of each. In his *Psychology of Efficiency* Rutgers has analyzed human methods of meeting new situations which involve motor processes. His material consisted of mechanical puzzles, usually of wire, in three dimensions. In order to solve the puzzle some part had to be removed thus necessitating manipulation as well as thought. In his twenty-seven subjects he found that the methods of solution ranged from the animal hit-and-miss method to the forming of a working hypothesis before the puzzle was touched, but in general in proportion as the problem was new the hit-and-miss method was approximated. These extremes remained in some cases even when the puzzle was learned. That is, some subjects, even when they could do it perfectly seemed unable to follow a plan, but did it as it were automatically, while others could describe each step in detail before doing it. When the subject took the puzzle and began to handle it, his movements were

to large degree random, and he might chance upon the one which solved the puzzle. His future success then depended upon the degree to which he could recall and attend to the movements made, and see their relation to the puzzle. Not infrequently memory was illusory, or a false hypothesis had been formed which prevented the subject from experimenting freely and hindered the solution. In the actual solving, there was a complicated interaction between random movements and attention to them. Sometimes the movement was accidental but the subject saw just as he made the movement that it would be successful; in other cases he could remember it well enough to succeed at once the next time. As a rule however the first accidental success served only to localize the point of attack, and further experimenting about this focus was necessary. Rutgers, like Book, emphasizes certain points in the learning. The first success with the puzzles, like the first short cut in typewriting, is likely to be accidental, but it is also likely to come only when the subject is in the best physical condition and is attending most closely. Then it is likely to be done more or less unconsciously for a time, but gradually to be perceived and be brought under volitional control. Book then goes into further detail in the study of acquiring skill in typewriting. After the first rapid stage of learning, the subject reaches the point of average attainment when it is very much harder to acquire a greater degree of rapidity or correctness, partly because the material has become familiar and so less interesting, and partly because few persons have had any experience in making the higher groupings. The learner tends to become lazy and remain at the same level, or on the other hand he tries to proceed too rapidly, and so fails in correctness as he progresses. To work at the optimum but not to go beyond it or fall below it is the important problem for each individual, and this again is a matter of wise control of attention. Nevertheless, Book emphasizes again and again, that the most effective control of attention is not obtained by direct means, but only by keeping in the best physical condition and by having the keenest interest in the work and the highest incentive to keep at it. He who says, "Go to, to-day I will acquire this or that definite degree of skill," is almost sure to require either too much or too little of himself. The psycho-physical organism is too complex for us to forecast its possibilities at a given time as yet.

This holds to an even greater degree of inventions. While it is generally true that the workman in a given trade is more likely to invent than one who knows nothing of the industry

in question, it is not essential. Even in a trade so technical as engineering Kent reports that of the 72 talented American engineers whom he studied 16% had not come into contact with machinery in boyhood and 17% reported that they had no especial mechanical interests in boyhood. On the other hand Kent says that in all the cases of which he knows, a boy who has made an engine before he is seventeen years old has later atttained eminence. That is, the early presence of mechanical interest and skill enables us to prophecy positively, but its absence does not make it safe to prophecy negatively, for it may be compensated later by unusual motivations and application.

Let us take up in more detail a specific invention, that of Watt, to see if possible how accidental manipulations or chance associations interact with the end in view and the working hypothesis. Watt is one of the engineers who showed his taste from boyhood. Adler would probably consider him an excellent case of compensation for organic inferiority. He was a sickly boy, unable to share the active sports of other boys, so that he was forced to amuse himself to large degree. He naturally enough imitated his father's work in his shop, and when fourteen years old he set up a forge for himself. His father sold instruments and also had a carpenter shop and the boy learned to use the various nautical and other instruments on sale or left for repairs. When eighteen years old he determined to be a maker of scientific instruments, and went to London and later to Glasgow to learn the trade. After various difficulties with the guild, because he did not wish to spend the required number of years as an apprentice, the University of Glasgow in 1757 gave him the use of a room and a half official connection with it. Here he made all sorts of mathematical and musical instruments, taking a partner later, and building a flourishing business.

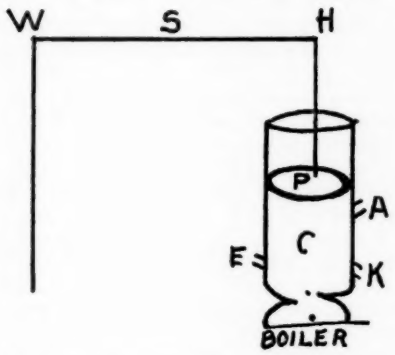
To understand the conditions under which Watt worked something must be said of certain other discoveries upon which the invention of a steam engine depended. Even the Greeks and Romans knew something of the power of steam, and later it was used to a small extent for melting ores, and for turning the spit. In 1663 the Marquis of Worcester described a pump to be run by steam to pump the water out of mines, but could not make his idea practical. Only thirty years later however, the Frenchman Papin discovered that if water is boiled in an air-tight vessel until it all turns to steam, and if the steam is then condensed by sudden cooling, a vacuum will be left in the vessel. Of course no vacuum

is perfect, but in Papin's the difference between the atmospheric pressure and that of the so-called vacuum was great enough to make a crude steam pump practicable, and Savery made this use of the vacuum eight years after Papin's discovery. The principle involved is very simple. There is a large steam vessel, the precursor of the engine cylinder, set over the boiler, with an opening between the two so that the cylinder fills with steam as the water in the boiler boils. The cylinder has three other openings: (1) There is a pipe leading down to the water in the mine, which is to be pumped out; (2) Another pipe leading to discharge the water after it has been drawn up, and (3) a third pipe by which the air is forced out of the cylinder. At first the water and discharge pipes are closed and the cylinder is filled with steam which forces out all the air. The steam is then condensed, and the water pipe opened. Since the pressure within the cylinder is much less than that outside it, the water is forced up into it till the pressures are equal. The water pipe is then closed, the cylinder again filled with steam and the discharge pipe opened and the mingled water and steam discharged.

This however was greatly improved by the Englishman Newcomen, who had a very pressing problem before him. In England the need of power for pumping the water out of the copper mines had become acute. The mines were extremely valuable, but they had been worked for a long time and had become so deep that the enormous suction pumps run by horses would no longer pump out the water. Many had been abandoned although the copper was by no means exhausted and additional ones were being closed all the time. Newcomen formed the idea of using Savery's pump with improvements. In the first place he wanted to use the pumps already in the mines, but to have a greater power attached where the horses had been before. That is, he wished to make steam work the handle of the pump up and down.

This necessitated a number of changes which can only be indicated here in the rough diagram. From W a chain runs down to the pump in the mine, and HW is a beam hung on a socket at S. From H a rod runs down to the piston P, which is essentially a smooth sliding cover to the cylinder, C. When the steam is forced up into C, the air is driven out through A as in Savery's engine and when the cylinder is full of steam the boiler is shut off from it, and the steam is condensed by a spray of water running in from E, the water being run off from the cylinder through K, leaving the vacuum in C. Then the pressure of the air outside the

piston forces the piston down at once, and with it the beam, which thus begins to work the pump at the other end. When the piston reaches the bottom of the cylinder it is drawn up to the top and the process begins over again. Newcomen's engine was improved by Smeaton, and for nearly a century it was used commonly in mines. But only 10% of the power was available for the pump, the rest being wasted in various ways. The piston made not more than three or four strokes per minute, and moved about fifty feet per minute, and the engine consumed twenty-eight pounds of coal to each horse power produced, though to-day but one and one-third pounds are needed per horse power. Wasteful though the Newcomen



engine was, it had considerable sale among mine owners because it was the only source of sufficient power to remove the water from the mines.

By 1760 however, it was failing to do even this in some instances, and when young Watt discussed steam with his friends we can not doubt that the deficiencies of the Newcomen engine and the practical need of more power were frequently touched upon. In any event, shortly before 1763 Watt learned that the University had a Newcomen model which had been sent to London to be repaired, and he put in a request that he be allowed to get it back and try his hand at it. This was granted and after a long delay the model reached his workshop. We can reconstruct to some small degree at least, the effect it had upon him. He was a maker of mathematical instruments and that means that he had a great love of exactness combined with remarkable deftness. From childhood he had taken his toys to pieces and not only

put them together again but often had combined the parts in new ways. When he got his forge in his fourteenth year, he made miniature cranes, pulleys, pumps, and so on, and out of a silver coin he made a punch ladle, still preserved. He also mended the various nautical instruments brought to his father, such as compasses and quadrants. Later when established in his rooms at the University of Glasgow, while waiting for a better class of work to come, he made musical instruments, and constructed a barrel organ for the first time, while in the second one that he made he added a number of improvements. He said of himself that he was always dissatisfied with others' work as well as with his own. It is easy to see how so wasteful a machine as the Newcomen engine would irritate a mind of this type, and almost inevitably lead him not only to mend the model given him but to experiment with it to prevent so much waste. Further, in 1759, when Watt was only twenty-three years old, his friend Robison, with whom he was continually making experiments and having discussions, suggested to him that steam might be used to drive carriages and Watt began to make a model of a steam engine, but was not very successful and laid it aside when Robison left Glasgow. Discussions with another friend, Dr. Black, however, kept the idea of steam power alive in Watt's mind, so that when he learned of the Newcomen model he made the request already noted. While waiting for it he experimented on a very small scale with the force of steam, using Papin's digester, and for cylinder an ordinary syringe only one-third of an inch in diameter, with a solid piston and stop-cocks put in to admit or shut off the steam. Tiny and crude though this apparatus was, he learned from it the expansive force of the steam upon the piston, and also the greatly increased elasticity and power of steam kept under high pressure. He saw the mechanical possibilities of this at once, but he could not make actual use of them because he could not get workmen skillful enough to make boilers that would be safe. When the Newcomen model finally arrived and was set up, as he supposed in perfect condition, after only a few strokes of the piston it stopped and would not begin again, though the fire was made as hot as possible and as much steam as possible produced. This was a challenge not to be refused. During the next year Watt and Robison tried various devices, in the course of which Watt stumbled upon the fact of latent heat, which his friend Dr. Black had already discovered and explained the theory of to him. Watt found that steam would heat six times its weight of water

from freezing point to boiling point, its own temperature. About the same time that he was making these experiments (his own accounts and Dr. Robison's, written some twenty years afterwards, do not give us the exact order of events, and differ in some instances with each other), he was also experimenting on both the boiler and the cylinder of the engine. The knowledge of the latent heat in steam made it very important not to waste any steam, and also to increase the heating surface of the boiler as much as possible in order to produce the greatest amount of steam from the smallest amount of coal. Accordingly he ran flues through the boiler, or built the boiler about the fire, made it of non-conducting materials, and so on. By degrees however he became convinced that the greatest waste was in the cylinder, and that in his small models the wastes were greater than they should have been according to the text book accounts. Particularly he found that too much steam was condensed in the cylinder, and that when he tried to condense it more rapidly by injecting more water, too much steam proportionately was wasted. After trying this out repeatedly, he found that water in a vacuum boils at lower temperatures than under usual atmospheric pressure and so he got steam and pressures which he was not expecting. In all this he was using a very small scale of models. Sometimes his cylinder would have a diameter of six inches and a stroke of twelve, or sometimes it would be only an apothecary's syringe, and a flask that would hold a pound of water. Again, a tea kettle would serve as his boiler. But by means of such crude and small apparatus, by the fall of 1764 Watt had reached certain conclusions. He was confident that the chief waste in the Newcomen engine came in cooling the cylinder. We have already noted that to get a vacuum in the cylinder, the air is first driven out by steam, and then the steam is suddenly condensed from 212° to about 100° by the injection of a stream of water. This of course also cools the cylinder, and when the steam is let in next time Watt found that from three-fourths to four-fifths of it condensed on the cold walls of the cylinder before any could be used in work. How was this waste to be prevented? Naturally, if the walls of the cylinder could be kept as hot as the steam, the steam would not be wasted in heating them. But how could the steam be condensed without cooling the cylinder? To cool the steam in the cylinder from 212° to 100° without cooling the walls of the cylinder at all was therefore the crucial problem in the invention of the modern steam engine.

Several months passed of which we know little. In the summer before Watt had married, and during this fall he was attending diligently to his proper business of instrument making, as well as his experiments with the engine models. In the following spring, probably in April of 1765, he went for a walk one Sunday afternoon on the Glasgow Green, and between the unromantic buildings called the wash-house, where the Glasgow washerwomen did their weekly rubbing, and the herd-house, the great idea flashed into his mind. We know no more of the details than that he had been thinking as usual of his engine. This central idea was that, to use Watt's own words, "as steam was an elastic body it would rush into a vacuum and if a communication were opened between the cylinder and an exhausted vessel, it would rush into it and might there be condensed without cooling the cylinder." It would then be necessary to draw off the condensed steam and the injection water from the condenser, but this could be done by a pump. He concludes, "I had not got farther than the golf-house when the whole thing was arranged in my mind." We might say carelessly that now the invention was made, but Watt still had four years of disappointment ahead of him before he could even take out his first patent, and ten or twelve before he began to get any financial returns. Watt was twenty-nine at this time.

In his own account, written thirty-one years later for his attorneys, he says that if he had been content merely to make the engine on this plan, thus saving the steam and fuel, he might have put it on the market very soon, but he wanted to make the cost less as well, and he very soon had in mind other devices which he believed would improve the engine more than they actually did. He says that his inexperience in "mechanics in the great" led him astray.

The next step was to see whether the idea would actually work. The next day Watt obtained a large brass syringe, 1¾ inches only in diameter and 10 inches long and put a tin top and bottom onto it to make it into his cylinder. The condenser consisted of two tin pipes only about 1/6 inches in diameter and 10 inches long, standing upright and joined at the bottom to the pump and all placed in a vessel full of cold water. A pipe, of course, ran from the condenser to the cylinder. In the piston rod he also bored a hole through which the water condensing when the cylinder was first heated could come, and when steam began to come out through it and through the condenser valve it was supposed the cylinder was full of steam. The valves were then shut and the vacuum

was made in the condenser by means of the pump, so that the steam rushed in from the cylinder. The piston of the cylinder at once rose in its turn, raising with it a weight of 18 lbs. attached to its rod. (The diameter of the piston was 1¾ inches.) The amount of steam used and the weights lifted were carefully noted.

At first, after the piston had risen it was allowed to fall by the atmospheric pressure on its top, when the vacuum was made in the cylinder below, but Watt realized very soon that the air going down the sides of the cylinder also cooled it (the old cylinder being open at top and air usually being only 70°-80°), and that it would be very desirable to close the cylinder at the top and have two pipes at top and two at bottom, to bring in and carry off the steam above and below the piston, pushing it down as well as driving it up by the steam pressure. The engine thus became a true steam engine as distinct from Newcomen's atmospheric engine and the piston a double-acting one. Thus a further saving of heat was effected. This modification seems to have been made even in the first tiny model, and in the larger one which Watt at once made there was also an outer case to surround the cylinder and be filled with steam, in order to keep its heat still more uniform.

Now Watt entered upon what was perhaps the most trying period in his inventing. He himself, as we have noted, was a maker of scientific instruments, with all the exactness of mind and skill of hand which that necessitates. The success of his engine depended entirely upon the presence of those qualities in the workmen who were to make its various parts, especially the cylinder and piston, but he could find no such workmen in the United Kingdom. The larger model which Watt himself made with the aid of a mechanic was good enough to *promise* great things, but the cylinder was imperfect so that the steam escaped at many places and the piston was far from air tight. The same was true of the still larger one which he built a little later, and also of those tried after he went into partnership with Roebuck. The difficulties with the imperfect shape of the cylinder, it should be said, were never overcome until years later when Mr. Boulton found the iron-master John Wilkinson. As long as the cylinder was imperfect the piston could only be relatively tight in it, though Watt did improve this to a considerable degree by the arrangements of collars which he put around the piston, the use of greases and oils, etc., with all of which he seems to have tried almost everything imaginable. From 1765 till

1770 he could not give as much time to the engine as he wished, but took up surveying as a business, and also made minor inventions along other lines. In 1767 he became acquainted with his future partner, Mr. Boulton. Mr. Boulton was the owner of the most famous metal works in England, and for some years he had been greatly interested in the possibility of using steam power in his factories, since he had not sufficient water power for the growing industry. He and Watt had for three years interchanged letters, and debated the possibility of a partnership, but Watt was already bound to Dr. Roebuck so that Mr. Boulton could not enter on the terms that he wanted. In 1770 Mr. Boulton asked Watt to send plans for an engine, which he would try to make at his works. This was done but the engine was no better than the others, though Boulton had the best mechanics in England working for him. Other attempts about the same time with older models, were equally failures and Watt began to think that his engine would never be a commercial success because he could not get skilled workmen to make it. Four years more passed in earning a living, suffering from ill health, and failing in his attempts to improve the engine, but in May of 1774, an agreement was finally reached with Boulton and Watt betook himself and his models to Birmingham. He had taken out a patent in the spring of 1769, but he had not as yet made a single engine for sale, although he had spent several thousand pounds in experiments besides all his labor.

At Soho Boulton's workmen set up the model over which Watt had worked so long at Roebuck's, and this time it worked better than ever before, though still open to much improvement. Boulton also began to get inquiries as to the nature of the engine, whether it could be used for mines, etc., and other men began to steal the plans of the engine or to invent on their own account. All this showed the demand and the financial gain to be made if the patent rights were protected. Boulton accordingly persuaded Watt of the necessity of getting an extension of time on his patent and after some trouble this was secured in the winter of 1775, for twenty-four years.

We should note at this point the invention of John Wilkerson, the iron founder, who introduced a new boring machine to make the large cylinders necessary for cannon and steam engines more accurate. The usual method at that time was to have the rough shape of the cylinder cast solid, and afterwards to bore the size wanted, but there was nothing to guide the borer, and so the hole was not likely to be perfectly straight. Wilkinson however, steadied the borer by a very

strong iron rod, along which the borer slid, so that whatever the shape given in the casting, the hole bored was perfectly straight and round. Nevertheless, when the first engine was made at Soho, Smeaton, perhaps at that time the most famous engineer in England, did not believe it would ever be practical on account of the difficulty of getting the various parts accurately enough made, although he fully recognized its superiority over other forms if this could be done.

Nevertheless Boulton and Watt began to sell engines, guaranteeing that their engines would do as much work as the ordinary engine, for half the expense in fuel, and in March, 1776, Boulton wrote that if they had a hundred small engines and twenty large ones on hand they could easily sell them all. He hoped to make one engine every two or three weeks, or from twelve to fifteen reciprocating and fifty rotative engines per annum. While Boulton managed the business end, Watt was occupied in making improvements and in setting up those sold. He was constantly trying new materials for collars or lubricants to the cylinder, changing the form of the condenser so that it would cool the steam more rapidly, changing the position of the valves and making them tighter, and so on. In one of the first engines made at Soho we are told that it made 500 strokes with 2 cwt. of coals, while a month later it made 2,000 strokes with 1 cwt.

For some years Watt spent most of his days setting up engines, and from 1780 to 1785 he took out five patents on different inventions: a new method of copying letters, a machine for drying linen and muslin by steam; the very important one on methods of applying the power of steam engines to produce a rotary motion around an axis, which made steam applicable to all mill machinery; an additional patent on the steam engine itself. In this last are specified the important principles of using the expansive power of steam, the double-acting piston, the double engine, a toothed rack and sector to guide the piston movement, and a rotative engine or steam wheel. Both the expansive power and the double-acting piston had been known to Watt from about 1767 but he had not used them on account of the difficulties involved in making them. Finally, Watt patented methods of converting circular or angular motion into perpendicular, along with many minor improvements, and a device by which the steam engine would work a tilt hammer, of which combination he writes with great pride in 1783 that the engine had a cylinder of 42 inches diameter, and a stroke of 6 feet, making as much as 50-60 strokes per minute. It would work a

hammer of 7½ cwt., raised 2 feet high, which could be made to strike 300 blows per minute.[1]

Boulton and Watt got their profits from their engines in the saving made over the common ones, that is, one-third the saving of fuel to be paid either annually or semi-annually. They found so much tendency among the men to steal the coal and to deceive them, that Watt set to work upon a counter, which should record the number of strokes made by the engine and thus enable them to calculate the amount of steam made and coal burned. Among other improvements were those of the throttle valve, governor, steam gauge, indicator, and smoke consumer, which also burned the fuel more completely.

During these years of invention, as before, Watt suffered a great deal from ill health, severe headaches, and low spirits. He speaks of his health being so bad that he fears he can not hold out much longer, he longs for a rest for his weary bones and laments the loss of the inventing power, although it was really as active as ever.

As to the inventive process itself the reader of his biographies is most impressed by the fact that the actual making of an engine valuable for practical purposes lagged so far behind the successful model. The theory was well worked out and the skill in making small models was acquired by Watt ten years before a large working engine could be turned out. Watt himself never seems to have set about acquiring the skill necessary for casting perfect cylinders, nor to have turned his inventive ability upon that problem. This is rather strange, for as far as we can judge from his letters he realized that the difficulty lay in getting a perfect cylinder. Or perhaps we should say that he realized that the difficulty lay in getting the piston perfectly tight in the cylinder, and thought that he might accomplish this by means of his collars and lubricants. At any rate he seems to have expended his energy in that way and to have used the hit-or-miss method to the extreme there. In trying out different shapes for the condenser and boiler, the part played by theory was more important, for he wished to get as much surface as possible for the water or the fire to play over.

It is an interesting question whether, if Watt had not found Boulton and Wilkinson, who took charge of the busi-

[1] To-day a piston travels only at moderate speed when going 1,000 feet per minute in a cylinder three feet long, and makes 166 revolutions. It costs about eight cents to get one horse-power for twenty-four hours.

ness management and of the actual making of the large cylinders and engines, he would ever have succeeded in the practical application of the theory; whether his engine would not have remained merely a model, useful in the laboratory to illustrate various physical laws, but of no use to industry. Boulton made over one of the most important branches of the iron trade in order to get a workable engine, and in order to do that he trained his workmen to a degree of skill and accuracy before unknown either in England or on the Continent. On the other hand, it is altogether doubtful if he would have appreciated the fact that the failure of the engine was due to numerous small defects in its parts which allowed leakage and waste, had not Watt been constantly on hand in the foundries to indicate these defects, and had he not been the one who set up the engines sold and stayed by them until they worked according to the contract. That is, Watt showed the points at which the theory failed in practice because the machine was badly made, while Wilkinson and Boulton wrestled with the intractable material, poor tools and unskilled workmen. If Watt had not had a firm conviction acquired from his success with his small models that his theory was correct, and if he had not also had the exactness developed by his work with fine tools on scientific instruments, he would probably have been unable to convince Boulton of the practicability of his engine.

In his biographies we do not get nearly enough account of the complicated interplay between theory and the manipulation of the models or the actual engines, but the fact that for years Watt himself set up the engines sold and stayed by them until they were in good working order, while during these same years he was adding the important conveniences of the throttle valve, counter, indicator and governor, as well as others less well known, shows how close the interaction must have been.

We are thus able from the available data to outline roughly three stages. We do not know whether he had any especial interest in steam before his discussions with Dr. Robison in 1759. From 1759 to 1763 there was a preliminary period of discussion, intermittent experiment, discovery of some of the laws of steam pressure, etc. This was followed by a more intense period of application introduced by the work with the Newcomen model and culminating in the image of the separate condenser, which within a day was tested in the first tiny model. This model in turn was followed almost at once by two or more larger ones, and in the course of

this close interaction between manipulation and thinking the double-acting piston was invented, and many other things were invented and tried out which did not work, such as a wooden case for the cylinder. As far as we can judge, the constructive aspect, the shooting together of relatively unconnected images into the constellation that we call the steam engine, occurred in a period of only about two months, during April and perhaps May of 1765. It had been preceded by the long practise period beginning in 1759, becoming more intense from 1763 on, and finally culminating in the invention.

Another practice period follows from 1765 to 1774, when he began his partnership with Boulton at Soho. During these years there seems to have been little addition to the theory, but all sorts of combinations of perceptions and images tried with a view to stopping the various leakages of steam and heat. These attempts however were not very successful. The larger engines made worked just well enough to keep alive the belief of Watt and Roebuck but not well enough to try to sell them. Watt's energies were much divided. He was obliged to take up surveying in order to support his family and pay the debts incurred in his experiments with the engine, and he made various minor inventions along quite different lines. During these years therefore he did little more than mark time. In other words, he was practicing with steam, becoming habituated to it, but he was not working with the intensity and concentration which Book found essential for the step up to the next level. He was on one of the learning plateaus.

When he went to Soho however, in 1774, Boulton provided the necessary stimuli for progress. In the first place, the partnership contract cleared up the financial tangles and freed Watt's mind from them. In the second place, under Boulton's urging, Watt obtained an extension of his patent rights for twenty-four years, so that he felt that he would get some financial profit from his invention. Finally, within six months Boulton began to take orders for engines and to guarantee that they would do a certain amount of work, so that Watt was under the pressure of making the engine at least as good as the contract provided for. The effect was immediate and great, as we have already seen, in one case the number of strokes being increased fourfold for one-half the previous amount of fuel. Within these years from 1774 to 1785 we get a combination of practice and invention which would be most instructive had we only the details. Watt was setting up the engines sold, instructing the engineers how to

run them, and constantly making the minor improvements already referred to. His fancy was constantly playing over the engine to note the weak places and possible improvements, and the constructive process again culminated in the patents taken out between 1780 and 1785, some of which were nearly as valuable commercially as the original one.

Had we the biographical data, there can be little doubt that we should be able within each of these larger periods to mark off sub-periods of the same kind, and to establish correlations between the condition of his health and his inventive power. Space is lacking here to detail the course of infringement of his patents, or his recognition of the social need and value of the steam engine. Suffice it to say that he had a clear consciousness of the benefit to humanity, but in reading his life one gets even more the impression that he kept at the work primarily because his instinct for handling things and seeing what would happen from all kinds of combinations was so strong. He fussed over all kinds of devices that turned out impractical and over many things unrelated to steam. One might almost say that his hands had a constant itch which nothing but work with physical things could stop and that with so much play with things the law of chance alone would ensure some useful things being discovered or made. On the other hand, the focussing of his interest upon steam seems to shows his sensitiveness of response to his environment and to this great industrial need of his day. Why steam made so strong an appeal to him we can not say. Did it typify the power of spirit over matter, of mental energy over physical inertia? Was his struggle against his own bodily weaknesses transferred to this plane? This is purely speculation, but it is at least interesting to see how the weakly boy harnessed the strongest force of modern civilization, making mere size and muscle of less account than ever before.

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GEOTROPISM IN ANIMALS[1]

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I. The word "geotropism" was first invented by Frank, a German plant physiologist, in 1868 (19). The word "tropism" with prefix, helio, light, however, was first used by De Candolle, a French plant physiologist, in 1835 (39, p. 154). Tropism, as you all know, is a Greek word meaning "to turn." Geotropism is, therefore, "to turn" toward or away from the center of the earth or the force of gravity. Some writers use "geotaxis" instead of "geotropism." Taxis, a Greek word again, means "to arrange." According to them, "geotropism" is for plants which are not motile, and "geotaxis" for animals which are motile. But I prefer "geotropism" rather than "geotaxis" for the reason that the reactions of plants and animals, motile or not motile, to the force of gravity are fundamentally the same thing (cf. 40).

Many animals react to the force of gravity; most of them turn their anterior ends away from the center of the earth, and a few of them toward it. The former are called negatively, and the latter positively geotropic. The phenomena are negative and positive geotropisms.

Paramecium, for example, which is one of the unicellular organisms, orients itself with its anterior end upward, and swims in that direction; thus against gravity. Among the coelenterates, geotropism is shown by certain hydroids; by Antennularia antennina—a plant-like animal—for example, whose "stems" have a tendency to curve upward, and their "roots" a tendency to grow vertically downward, though the geotropic curvature of the "roots" is not so precise as in the "stems." The "roots," in this case, are positively, and the "stems" negatively geotropic. If you cut off a piece of the "stem," and reverse it, that is, place the "stem" end down

[1] This popular paper was read by the writer at the sixth annual meeting of the Minnesota Psychological Conference, which was held at the University of Minnesota, March 27, 1914. The text has not been changed since except to add foot-notes.

and " root " end up, it will regenerate " roots " at the lower end of the piece, which having been the " stem " end, would normally have grown upward, and will regenerate a " stem " at its upper end (31, pp. 494-495). Now, the question arises: what makes the animal orient itself toward or away from the force of gravity?

II. For students of physiology all animals, human animals inclusive, are " chemical machines " in which extremely complex processes are going on. Naturally, therefore, physiologists have attacked the problem of orientation of animals by gravity from a purely physical and chemical viewpoint. Ever since Schwarz first took up the problem in 1884, in unicellular organisms, bacteria, Euglena, Chlamydomonas, Desmid, Paramecium, and Spirostomum, have been subjected to quite extensive experiments for this purpose. Unfortunately, however, different investigators have offered varying explanations for the phenomena, though this problem we feel, is nearly settled now.[2] Limited time and space, however, prevent our dwelling on it here. We shall therefore simply refer to the names of various theories, namely, mechanical theory, pressure theory, resistance theory, and statocyst theory.

The first three theories as applied to unicellular organisms, having been experimentally shown to be fallacious, E. P. Lyon, in 1905, suggested the last theory. He applied to the unicellular forms, the ideas previously advanced by Goltz, Mach, Breuer, Bethe, Loeb, Verworn, and many others to explain orientation in the higher forms. Lyon's view was based on some experimental results, tending to show that the paramecium contains protoplasmic materials of different specific gravities.[3] " For internal stimulation," according to him, " the relation of the parts of the cell to each other must be changed in some way by gravity. Stresses or pulls which occur when the organism is in one position with respect to the vertical, must be changed in another position " (33, p. 429).

To illustrate the point, let us take some experimental examples. Eggs of sea-urchin, annelids, frogs, etc., when strongly centrifuged, separate into three layers, i. e., light, middle, and heavy.[4] There is no doubt, therefore, that dif-

[2] *Cf.* 24 and 34. The writer is also preparing a paper, " Further studies on the geotropism of Paramæcium caudatum and a direct proof that the animal contains protoplasmic materials of different specific gravity," in which he will attempt to settle this problem.

[3] The writer's recent experiments, not yet published, on Paramæcium caudatum, furnish direct evidence to prove that it is the case.

[4] E. P. Lyon was first to show these results (34).

ferences in specific gravity exist in the protoplasm of the animal cells. As has already been pointed out, the view of the statocyst theory of geotropism in paramecium accords with that of higher animals. Some crustacea, Palaemonetes, for example, have "irregular grains of sand mingled with other fine mineral particles and organic detritus" "in the basal segment of the antennule," which are the statoliths[5] for the organisms. The statoliths in question play an important rôle in the geotropic orientation of the organism. This has been proved by Prentiss' experiments as follows:

The statoliths are removed from the sacs of Palaemonetes by lifting the lid which covers the aperture, and forcing a fine jet of water into the cavity. Most of the sand having been thus washed out, the animals are placed in an aquarium upon the floor of which iron filings have been scattered and are allowed to remain until the iron particles have been taken into the sac in place of grains of sand. The shrimps (Palaemonetes) are blinded by painting the eyestalks with a mixture of lampblack and shellac. A *strong* electromagnet is then used. The pointed end of the magnet is held about 3 cm. from the statocysts, at one side of and a little ventral to them. Animals with normal statoliths, if blinded, do not respond at all, and are apparently unaffected by the proximity of the magnet; they keep their normal position, dorsal side up, with the sagittal plane of the body coincident with the direction of gravity. If not blinded, they simply move slowly away from the magnet when it approaches too near. When, however, the magnet is brought into close proximity to statocysts containing iron filings, the dorsal side of the animal is turned, not toward the magnet, as might be expected if the changed position were due directly to the action of the magnet on the iron filings, but away from it. If the magnet is changed to a position on the other side of the shrimp, the turning is in the opposite direction, still away from the source of attraction (39, p. 239). "There is only one explanation for this turning of the body away from the attracting force, and that is a very simple one. Under normal conditions the body of the shrimp is oriented with reference to gravity, and its dorsoventral axis approximately corresponds to the direction of this force. If the shrimp rotates around its chief axis either to right or left, say 90°, the direction of the pull of gravity on the statoliths is at once changed, and through the medium

[5] Verworn (47) first suggested the use of the word "statolith" instead of the word "otolith," which is generally used. The writer thinks it is desirable to accept Verworn's term.

of the latter other sensory hairs of the sac are stimulated. As a result, the shrimp turns back in a direction opposite to that in which it was rotated, until it is again in a normal relation to the direction of gravity. The employment of the magnet has no other effect than merely to change the direction of the orienting force. This is no longer that of gravity alone, but the *resultant* of the two component forces, gravity and the pull of the magnet. The animal now maintains its swimming position in reference to this new line of attraction, its dorso-ventral axis coincident with that line, and as a result the dorsal side is turned away from the magnet" (39, p. 240). Thus we can see that the pull of gravity on the statoliths in Palaemonetes plays an important rôle in the physiological function of equilibrium.

In connection with this, let us cite another interesting and important example from the same work. In lobsters, the larvae after ecdysis have no statoliths, and may be kept without them for one or two days, if they are placed at once after ecdysis into filtered sea-water. The effect of the lack of statoliths on the equilibrium of the animals can be thus observed. Within two hours after moulting, most of them swim about actively, and eat greedily when fed with bits of crab's liver. In swimming, however, they show quite marked abnormality. "There is both rolling from side to side, and 'pitching' forward and backward; often they swim with the ventral side uppermost. Much more easily overturned than normal larvae, they do not right themselves at once, but if turned upon the back, will continue to swim in that abnormal position. If blinded, the loss of equilibrium is still more marked. All these conditions are in strong contrast to the actions of the normal free-swimming larvae of these stages, which conduct themselves in the characteristic manner" (39, p. 238). These abnormalities, the result of the loss of equilibration, disappear at once when the larvae are allowed to obtain statoliths (39, p. 239). There is, therefore, no other explanation than that the statoliths, which are acted upon by the pull of gravity, maintain equilibrium in the line of the direction of gravity. This case is very important, because when we come to consider the geotropism of the higher vertebrates on which very extensive experiments have been made, we shall see that vertebrates deprived of their statoliths show the same abnormal phenomena manifested by lobster larvae without statoliths. This must be borne in mind.

III. Gravity, however, is not the only force which affects the behavior of animals. Many forces—light, contact stimulus, chemicals, temperature, and so forth, may act together. This leads to quite intricate results. Marine snails, for instance, which have statoliths, are naturally negatively geotropic.[6] But they are also negative to light. As affected by gravity, therefore, the animals are forced to crawl upward, but when exposed to light, they have to crawl downward. If the effective "strength" of gravity which depends on the position of the animals, is exactly equal to that of light, the animals might be stationary as a resultant of the two forces. If this is not the case, however, the stronger force might overcome the other. Gravity, of course, is constant—the pull of about 980 dynes—and always is exerted vertically. But the effective force exerted on the animals depends upon the position of the surface on which the animals may crawl. The exertion required to enable the animals to move on a horizontal surface is less than that required on a vertical surface, where the maximum force must be exerted. On the other hand, the intensity of light naturally changes, and can be artificially changed.

Suppose strong sunlight is falling vertically down, and the surface, on which the animals are crawling, is situated vertically. What direction must the animals take? The results of my experiments indicate that many of them—say 75%—crawl down. The light stimulus seems thus to be stronger than that of gravity. If you cover the vertical glass on which the snails are crawling down in direct sunlight with a dark box, you will be surprised to find the snails crawl upward in a few seconds; then, if you expose them to direct sunlight again, they will crawl down in a few seconds. They thus change their "minds" very rapidly!

Suppose again, we conduct an experiment in a room where there is no direct sunlight and place a vertical surface for the animals to move on. What must the animals do this time? Nearly all, if not all, crawl upward. Here is a problem for the psychologist, that is, a problem of "attention." Is that "attention" which causes an animal to go down or up, when it is stimulated by the relatively stronger of two stimuli focused by an idea or train of ideas? Other things being equal, is it true that the greater the intensity of an experience, the greater its clearness? Or, is "attention" something directed by physical and chemical changes which are

[6] A paper, "Studies on the Geotropism of the Marine Snail, Littorina Littorea," is ready for publication.

produced by the relative intensity of light or gravity in the protoplasm of the cells, especially in a photosensitive or geosensitive region?

This point will soon become clear if we consider the reversibility of geotropism and heliotropism in the larvae of the marine annelid, Arenicola cristata. The larvae are naturally negative to gravity and positive to light. If you add 25 cc. of isotonic $MgCl_2$ or $CaCl_2$ solution to 25 cc. of sea-water, and transfer Arenicola larvae in this mixture, about two minutes later they all become positive to gravity and swim downward, being oriented with their anterior ends in that direction, though their positive heliotropism seems not to be changed very much. Instead of $MgCl_2$ or $CaCl_2$, if you add 25 cc. of isotonic NaCl or weak acids to 25 or 50 cc. of sea-water, and transfer the larvae to this mixture, you will notice that the larvae become negative to light, though they, also, remain negative to gravity (24).

We may conclude that the change of the chemical composition, consequently of physical property, of the surrounding medium changes the geotropism and heliotropism of the larvae, although we do not yet know what change occurs in the organisms themselves.

Let us take another example to illustrate this point. We have already seen that Arenicola larvae become positive to gravity on addition of isotonic $MgCl_2$ or $CaCl_2$ solution to sea-water, though their light reaction is not affected very much. On the other hand, the larvae become negative to light on addition of isotonic NaCl solution to sea-water, though they remain negative to gravity. Now, it is well known among physiologists that $CaCl_2$ or $MgCl_2$ antagonizes the action of NaCl on organisms. In accord with this, if you add 5 cc. of isotonic $CaCl_2$ solution to the mixture of 25 cc. of isotonic NaCl and 25 cc. of sea-water, you will find that the reversibility of positive heliotropism of the larvae is very much retarded. What does this mean? This seems to mean that mutual antagonism of $CaCl_2$ and NaCl neutralizes the specific effect of each salt upon the larvae. This is physiologically of great significance. We seem therefore to be driven to the conclusion that both geotropism and heliotropism in animals are physico-chemical phenomena, and even such a problem as that of "attention," or the "initiative" of attention, as Royce expresses it, might be attacked by physico-chemical means instead of by entangled terms of consciousness (Cf. 10, 22, 41 and 48).

IV. It is well known that many insects show negative geotropism, but we cannot dwell on it here. So let us briefly

consider geotropism in still higher animals—the vertebrates, including mammals and man. Since Flourens experimentally showed in 1824 that extirpation of the vestibule and semicircular canals caused marked disorders of equilibration, immense energy has been spent by physiologists upon the problem of a sense of equilibrium in fishes, birds, rats, dogs, cats, etc. In normal animals the statoliths which are analogous to those of lower animals are present in the utriculus and sacculus. That the incidence of the pressure of the statoliths on the hairs will vary according to the position of the animal, so that any change in the position of the head will be at once attended by alteration in the nerve fibres which have been stimulated by the pressure of the statoliths (Cf. 46, pp. 449-450), and therefore in the nature of the impulses regulating the locomotion and the maintenance of the equilibrium of the animal (a theory agreed to by most, but not all, investigators) has been already considered in reference to the "iron statoliths" of Palamonetes, to attract which a strong electromagnet is employed.

On the other hand, the animals—fishes, birds, or dogs—which are deprived of the statoliths, or in which the semicircular canals have been destroyed, show inability to coördinate the muscles used in standing, locomotion, or flying. "The character and extent of these results vary with the number of canals injured, and indeed, show a more or less definite relationship to the several canals. When the horizontal canal is cut on one side in pigeons, the animal makes movements of the head in the plane of that canal, and if the similar canal on the other side is also sectioned, these movements are more pronounced." "When all three canals are cut on one or both sides, the animal shows a distressing inability to maintain a normal position. The head is twisted, it is not able to stand unless supported, and any attempt at walking or flying results in violent forced and incoördinated movements. The animal makes continued somersaults at each attempt to stand or walk, and the head is kept in spasmodic, forceful movements, which may produce injury or death." "It should be added that results of this character are obtained only when the membranous canals are injured. If the bony canal alone is cut, and even if the perilymph is removed by suction, no such effects are obtained" (21, pp. 399-400). These descriptions remind us of the observations on lobster larvae, already referred to, which were kept without statoliths.

In man, as in the shrimp, it is the statolith organ which determines the behavior in relation to the force of gravity. The statolith organ is therefore responsible in part at least,

not only for the maintenance of equilibrium, but also for the sensations which enable a man to orient himself and to know the position in which he happens to be at any given moment. There has been, of course, no experimentation on man deprived of the statoliths, or with the semicircular canals destroyed. But clinical data (1 and 42) point to the same conclusion, and cats and dogs have served for further proof (43).

V. As indicated briefly above, the facts regarding injury to and stimulation of the semicircular canals and the statolith organs, are very numerous, and, on the whole, fairly concordant. Their interpretation, however, has offered great difficulties, and many views have been proposed. Almost every investigator, in fact, has, to some extent, varied in his interpretation of the precise functional significance of these organs. We can, therefore, understand why there are many theories concerning them.

But a consideration of the structure of the statolith organs[7] shows at once that the incidence of the weight of the statoliths on the hairs of the maculae in the utricle and saccule will vary according to the position of the head, or of the animal's body. The nerve-endings stimulated by the weight of the statoliths will therefore vary according to the position of the head, or of the animal. The impulses of the stimulated nerve-endings will flow to the central nervous system. A reaction of the animal will obviously be the result (46, p. 680-681).[8]

When we have thus considered, though very briefly, geotropism in animals from the unicellular organism to man, we can fairly understand what an important rôle as stimulus the force of gravity plays in the physiology of animals in general. Consciousness, on the other hand, seems to play little part in the orientation of animals to gravity.

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A COMPARISON OF REFLEX THRESHOLDS WITH SENSORY THRESHOLDS—THE RELATION OF THIS COMPARISON TO THE PROBLEM OF ATTENTION

By E. G. Martin, B. D. Paul, and E. S. Welles
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In a series of papers from this laboratory[1] variations in the sensory threshold for faradic stimulation in man under various conditions have been described. The assumption has been made throughout the series that these variations in threshold result largely from changes in the central nervous system, and that they may be used, therefore as indicators of central nervous changes. The chief basis for this assumption is the observation that the diurnal variations in sensory threshold parallel closely variations in voluntary muscular activity as determined by ergographic fatigue.[2] Although no theoretical considerations nor any experimental data incompatible with this assumption have come to our attention we have thought it worth while to carry on an investigation designed expressly to test the validity of the use of the sensory threshold as an index of the general state of the nervous system.

The test consisted of repeated comparisons, extending over a considerable period, of the threshold of an easily evoked reflex, the winking reflex, from faradic stimulation of a selected spot on the lower lid, with the sensory threshold for the same spot on the lid. In this comparison the receptors and the afferent pathways as far as the central nervous system are presumably the same for both tests. If our present understanding of the functioning of the nervous system is correct the pathways within the central nervous system must be quite different. That for completion of the reflex would be pictured as a chain of neurones within the brain stem, leading ultimately into the efferent neurones for the muscle

[1] Grabfield and Martin: American Journal of Physiology, XXXI, 1913, 300; Martin, Bigelow, and Wilbur: Idem., XXXIII, 1914, 415; Martin, Withington, and Putnam: Idem., XXXIV, 1914, 97.

[2] Grabfield and Martin: Loc. cit., 308.

of winking; the path for the sensory perception, on the other hand, would be traced into the cortex of the cerebrum.

One would naturally suppose that the cerebral cortex, since it is the most highly organized portion of the nervous system, should also be the most variable. If the sensory threshold is a valid indicator of cortical condition it would be expected to show more pronounced fluctuations from time to time than would the threshold for such an activity as the reflex, which presumably involves less unstable nervous elements.

Method. For applying faradic stimuli one "indifferent" electrode and one stimulating electrode were used. The "indifferent" electrode consisted of a small brass plate about which several layers of absorbent gauze were wrapped. The electrode, well moistened with physiological saline, was applied to the forehead and secured in place by means of bandages about the head. A satisfactory stimulating electrode was secured only after much experimenting with various designs. The one finally used, which gave excellent results, consisted of a short piece of rubber tubing, 7 mm. inside diameter, passed through a hole in a common cork so that about 3 mm. projected beyond the end of the cork. Into the opposite end of the rubber tube from that which projected was inserted an amalgamated metal bar (copper at first, later, for greater durability, zinc). This bar bore a small binding post. It was secured in the tube with sealing wax. The tube next the metal bar was filled with calomel paste. On top of this, and filling the projecting tip of the tube flush to its edge, was a paste of kaolin with salt solution. When the tube filled with this paste was placed in contact with the spot on the lower lid which had been determined experimentally as the best for evoking the wink reflex, the cork rested against the cheekbone, and a simple bandage around the head held it securely in place.

Thresholds were determined quantitatively according to the method developed by one of us.[3] Through the kindness of Drs. Southard and Adler, of the psychopathic department of the Boston State Hospital, we were permitted to use the apparatus belonging to that institution for our observations. We take this opportunity of expressing our appreciation of their generosity.

For the routine work of the Psychopathic hospital the complete determination of sensory thresholds in terms of β units[4] has been found to involve too great a strain upon the

[3] Martin: The measurement of induction shocks. New York, 1912.
[4] Martin: Loc. cit., 76.

patients. For that reason the determination of tissue resistance in each subject is not made, and at the time we were carrying on this investigation the equipment for making resistance measurements was lacking. Our results are in terms of Z units,[5] therefore, rather than in terms of the more exact β units. For the particular purpose of this study Z units suffice fully, as we shall show later, although there would have been an advantage in being able to express our data in β units, chiefly to make them more readily comparable with the data of other investigations.

Observations. In this work two medical students, P. and W., young men in good health, acted alternately as subjects and observers. Sixty-six readings were made upon W. and 65 upon P. The observations were commenced March 29, 1914, and terminated April 30, 1914. No set time of day was selected for taking readings. On the contrary, it was thought desirable to obtain them at irregular intervals. On some days four readings were made on each subject; on others only one. Two hours was the smallest interval between readings on the same subject.

Save that the region of stimulation was the lower lid instead of the finger tips and that tissue resistances were not measured, the determination of sensory thresholds was according to the method of Grabfield and Martin.[6] Promptly upon the completion of the sensory determination the subject seated himself directly in front of the observer with his eyes well illuminated, and the threshold of the winking reflex was established. As a matter of fact, the attempt was made to establish two such thresholds, one for the least perceptible movement of the eyelid, and the other for complete closure of the eye. The latter of these was found to be more accurately determinable, and was finally adopted, therefore, as the reflex threshold to be used. Care was taken to avoid errors through mistaking spontaneous winks for those resulting from the test stimuli.

Results. In both subjects the sensory threshold was markedly lower than either of the two reflex thresholds studied. For subject P. the average values of Z from 65 experiments were; sensory threshold, 405; threshold of least perceptible lid movement, 578; threshold of complete closure of eye, 816. For subject W. the average values of Z from 66 experiments were: sensory threshold, 504; threshold of least

[5] Martin: Loc. cit., 73.
[6] Grabfield and Martin: Loc. cit., 303.

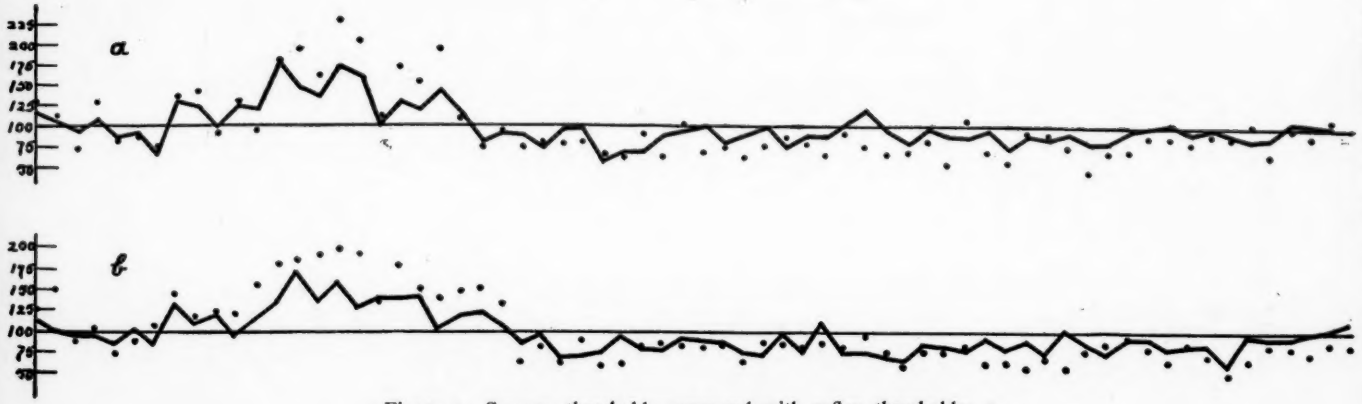

Figure 1. Sensory thresholds compared with reflex thresholds: a, subject P; b, subject W. The thresholds are expressed in terms of percentile divergence from the mean. In each figure a horizontal line is drawn at the level of the mean threshold. The data are set down in chronological sequence. The irregular solid line connects the successive values of the reflex threshold. The dots represent the corresponding sensory thresholds.

perceptible lid movement, 690; threshold of complete eye closure, 990. As one of us has shown elsewhere,[7] Z units express stimulation strengths only approximately, since they take no account of tissue resistance nor of the manner of electrode contact, although where the general experimental conditions are kept as constant as they were throughout this investigation, the error is not likely to be very large.[8] However, *relative values* can be accurately stated in Z units so long as secondary resistance and electrode contact remain constant. These conditions were fulfilled in individual experiments of this series. The relation of reflex threshold to sensory threshold *in any given experiment* is therefore accurately known, within the limits of observational error.

If the mean of all values of Z for the sensory threshold of a single subject is determined, and this mean is compared with the value of Z for any single determination, the extent of departure of the individual Z from the mean depends in part upon the fact that the Z unit does not express with entire accuracy the true value of the stimulus, and in part upon an actual difference in threshold of this particular reading as compared with the mean. The same factors enter to account for divergences of individual reflex thresholds from their mean. However, in any given experiment, the extent of divergence, which enters through error in the accuracy of the Z units as expressions of stimulation strengths, must be exactly the same for both sensory and reflex tests. Therefore, if, in any experiment, these observed thresholds show different degrees of divergence from their respective means they are actually as well as apparently, unequally divergent, and the one which, in terms of Z units, appears to be the more divergent, is so actually. Whatever conclusions may legitimately be drawn from study of the relative divergences of the two sorts of thresholds from their respective means are therefore justified.

For convenience and ease of comparison our results are presented in terms of percentages. The method of working these out is that used by Grabfield and Martin.[9] We have six sets of data; a series of sensory thresholds; a series of thresholds for least perceptible reflex lid movement, and a series of thresholds for complete reflex closure of the eye for each subject. For each set the mean was determined. These mean values are given above, pp. 430ff. The individual

[7] Martin: American Journal of Physiology, XXVII, 1910, 228.
[8] Martin: Ibid., 232.
[9] Grabfield and Martin: Loc. cit., 307.

thresholds were reduced to percentage terms by means of the formula: mean threshold; 100 = individual threshold: ×. By this scheme reflex and sensory thresholds become directly comparable. To bring out the points we wish to make the thresholds for complete reflex closure of the eye are compared with the sensory thresholds. The data from the thresholds for least perceptible lid movement are confirmatory of our conclusions, but the experimental determinations seemed to us less certain, and their inclusion seems not to be essential. Figure 1, a and b, gives the results of our two series, expressed in per cents. In both our subjects the thresholds for the reflex show on the whole markedly less divergence from the mean than do the sensory thresholds. The percentage divergence of any individual reading is simply determined by subtracting its "reduced" value from 100 if it is below the mean, or subtracting 100 from its "reduced" value if it is above. The average of all the percentage divergences thus determined for a single series of thresholds serves as an expression for the "tendency to diverge" of the members of that series. Expressed thus our results are: for reflex thresholds, subject P. 17.3, subject W. 20; for sensory thresholds, subject P. 28.6; subject W. 31. Detailed analysis of our data brings out even more strikingly than do the above averages the greater "tendency to diverge" of sensory as compared with reflex thresholds. Thus in subject P. in 50 out of 65 experiments, and in subject W. in 47 out of 66 experiments the reflex thresholds are nearer the mean than are the corresponding sensory thresholds. The reflex thresholds group themselves, on the whole, within a much narrower range than do the sensory. Thus the range of "reduced" thresholds included between values 75 and 125 contains 77 per cent of the reflex thresholds for P. and 71 per cent for W.; whereas the same range includes only 57 per cent of the sensory thresholds for P. and 50 per cent for W. Of individual thresholds varying from the mean more than 50 per cent the reflex series show only 5, 3 for P, and 2 for W. The sensory series, on the other hand, include 19 such wide divergences, 9 for P. and 10 for W.

The summaries just presented are based upon our entire series of experiments. Reference to the figure shows that through a period of the investigation the thresholds, reflex and sensory, for both subjects were considerably higher than during the remainder of the time. This period of high thresholds began on April third and ended on April tenth. So far as we are aware there was no change in the procedure during

this period, yet various considerations incline us to the belief that an unnoticed variation either in the preparation of the electrodes, their application to the body surface, or the direction of current through them, was the source of the variation in thresholds. The change in thresholds during this period was not duplicated in four other subjects who were making sensory tests with another apparatus at the same time that this investigation was in progress. That the electrodes, and not other parts of the apparatus, were responsible is indicated by the circumstance that on April sixth, in the middle of this period, a set of readings was made on each subject with the apparatus in this laboratory, but with the usual electrodes, brought from the psychopathic hospital for the purpose, and in these readings the high thresholds, characteristic of the period, were recorded.

As we believed the unusual character of these thresholds to be clearly instrumental, we felt justified in including them in our series, since any variations dependent on changes in the apparatus should affect sensory and reflex thresholds alike. To assure ourselves, however, that we were not in error in thus including these unusual thresholds, we have reexamined the two series with the period of high thresholds omitted. The series as thus amended show decidedly lower mean thresholds than those given above (pp. 430ff.). For subject P. the values are: sensory threshold, 51 experiments, 343; reflex threshold 735; as compared with 405 and 816 respectively, for the entire series of 65 tests. For subject W. the mean values from 49 experiments are: sensory threshold, 409, reflex threshold 864, as compared with 504 and 990, from the entire series.

The "tendency to diverge" from the mean is markedly less in magnitude in the amended series, but is still definitely greater for the sensory thresholds than for the reflex thresholds. The figures are: for subject P. reflex thresholds 10.8, sensory thresholds 14; for subject W. reflex thresholds 11.4, sensory thresholds 15.1. In maximal extent of divergence and in number of wide divergences, the sensory thresholds also continue to lead. The greatest reflex divergences are: subject P., 34 per cent, subject W., 36 per cent, as compared with sensory divergences of 52 and 83 per cent, respectively. The range of "reduced" thresholds between values 75 and 125 includes all but 8 per cent of the reflex thresholds for subject P., whereas 18 per cent of his sensory thresholds are without this range. For subject W. the corresponding figures are 6 per cent and 16 per cent respectively.

These results show clearly that in our subjects the threshold for faradic elicitation of the winking reflex is, on the whole, definitely steadier over a considerable period of time than is the electro-cutaneous sensory threshold. Are we justified in interpreting these results as supporting the conclusion that the sensory threshold is a reliable indicator of the general state of the higher nerve centers? An objection which may be urged against such an interpretation, and, in fact, has been so urged by a psychologist with whom the matter has been discussed, is that the fluctuations in sensory threshold may have been due chiefly to variations in the attention of the subject at the different periods of experimentation. Obviously variations in attention cannot be excluded in experiments of this sort. In fact, sensory threshold tests are of necessity in a sense, tests of attention. All that can be done is to instruct the subject to attend as strictly as possible to his part of the procedure. Strong features of this test are that it can be carried out very quickly and that the procedure required of the subject is of the simplest character, so simple, in fact, that the test has been applied successfully to numerous psychopathic cases.[10] The concentration of attention is not rendered difficult by the necessity of following complicated directions, nor is any marked feeling of strain involved. Our experience is that subjects, upon becoming accustomed to the routine, fall into a mental state during the course of individual experiments which seems to be about the same from experiment to experiment. Many psychologists are of the opinion that attention is ordinarily less fluctuating than has formerly been supposed.[11] Geissler[12] has shown that fluctuations in the time required for making mental additions agree strikingly with introspective estimates of degree of attention. In his opinion we are entitled, therefore, to base judgments of attention on observed addition times. He presents data from 12 series of experiments without distraction, made on 3 subjects (loc. cit., table II). The greatest fluctuations from average addition time do not exceed 31 per cent, and by far the greater number amount to less than 15 per cent. He found, moreover (loc. cit. p. 513), that complex schemes of distraction did not induce great variations in attention. According to these results the variations of sensory threshold due to fluctuations of attention would be expected to be much smaller than those obtained by us in this investigation, and

[10] Grabfield: Boston medical and surgical journal, CLXXI, 1914, 883.
[11] See Titchener: Textbook of Psychology. New York, 1910. 291.
[12] Geissler: This Journal, XX, 1909, 508.

we feel that except in so far as the attention is a function of the general nervous state it probably does not enter as a controlling factor in determinations of sensory thresholds by this method.

Certain data from these experiments appear to have a bearing upon the general problem of the fluctuation of attention. In the first place each individual sensory test contains within itself the means of determining whether during its course the attention has fluctuated to a serious extent. This means is afforded through the necessity of determining several thresholds in order that the value of β may be calculated.[13] If the several calculated βs fail to agree within a reasonable margin (ten per cent is the limit we allow[14]), the failure to agree is probably due to a fluctuation of attention. That fluctuations of attention would ever so relate themselves as to conceal their existence is extremely improbable. Determinations have been made in great numbers in this laboratory during recent years, and very seldom, in the hands of experienced workers, must experiments be rejected on account of failure of the calculated βs to agree within ten per cent.

In this particular investigation β units could not be determined because facilities for measuring secondary resistances were lacking, but in each experiment the routine procedure of establishing the usual series of four thresholds was followed, so that the course of the attention during individual experiments could be determined. As a matter of fact the agreement among the different threshold tests of individual experiments is as close in this investigation as in any others that have been carried on in this laboratory, showing that during the period of single experiments (about five minutes) important attention fluctuations have not usually occurred.

Of significance in connection with the problem of the fluctuation of attention from hour to hour and from day to day is the observation that the *direction of divergence* of individual thresholds from the mean was nearly always the same, in any single experiment, for both reflex and sensory thresholds. The two thresholds rose or fell together, but the sensory rose or fell further than the reflex. In only 10 of the 131 experiments were reflex and sensory thresholds on opposite sides of their respective means. In 92 of the 121 experiments in which they were on the same side of the mean the sensory thresholds were further from their means than were the reflex thresholds from theirs.

[13] Martin: The measurement of induction shocks, 77.
[14] Martin: American Journal of Physiology, XXXVI, 1915, 224.

The fluctuations from their means of the *reflex* thresholds may be taken as a base line. If the sensory thresholds had been found to fluctuate in exact harmony with the reflex thresholds we should have been obliged to conclude that there are no variations in higher brain centers that are not duplicated in lower centers. Had the sensory thresholds fluctuated irregularly about the line traced by the reflex thresholds a simple deducation would have been that variations of attention in the ordinary sense, were responsible. But when the sensory thresholds are seen to follow preponderatingly a course of greater deviation than do the reflex thresholds we feel justified in concluding that something more deep seated is indicated, and that we probably are dealing directly with attention as a function of the condition of the higher brain centers.

Summary

Comparisons in a long series of experiments of threshold stimuli for evoking the winking reflex with sensory threshold stimuli show that the former tend to vary from their mean value definitely less than do the latter.

The observation is made that the "direction of divergence" is nearly always the same for sensory as for reflex thresholds. This is taken to mean that the attention, under the conditions of these experiments, manifests itself as a function of the condition of the higher brain centers.

We draw the general conclusion that the value of the sensory threshold depends on the state of the higher nerve centers, and that the threshold may justly be used, therefore, as an indicator of such nervous state.

THE FREUDIAN METHODS APPLIED TO ANGER

By G. Stanley Hall[1]

The exact sciences consist of a body of truth which all accept, and to which all experts strive to contribute. Philosophy, however, like religion, has always been broken into sects, schools or parties, and the body of truth which all accept in these fields is relatively far less, and the antagonistic views far greater. Normal psychology, which a few decades ago started out to be scientific with the good old ideal of a body of truth *semper ubique et ad omnibus,* is already splitting into introspectionistic, behavioristic, genetic, philosophical and other groups, while in the new Freudian movement, Adler and Jung are becoming sectaries, the former drawing upon himself the most impolitic and almost vituperative condemnation of the father of psychoanalysis. With this latter schism we are not here concerned, but we are deeply concerned with the more general relations between the psychologists of the normal and those of the abnormal. With a very few negligible exceptions psychoanalysis has never had a place on the program of our American Psychological Association, and the normal has had little representation in your meetings and publications. This I deem unfortunate for both, for unsatisfactory as this sadly needed *rapprochement* is on the continent, it is far more so here. That the normalists in this country so persistently ignore the unique opportunity to extend their purview into the psychopathological domain at the unique psychological moment that the development of Freudianism has offered, is to me a matter of sad disappointment and almost depression. In reading a plea for Freud in our association of normalists, I am a *vox clamantis in deserto* and can evoke no response, and even the incursions of psychoanalysis into the domain of biography, myth, religion and dreams, have not evoked a single attempt at appreciation or criticism worthy of mention by any American psychologist of the normal. I have sought in various

[1] Read at a meeting of the American Psychoanalytical Association, New York City, May 5, 1915.

ways the causes of this reticence, not to say ignorance. While I received various answers, the chief one was to the effect that the alleged hypertrophy of sex in its gross pathological forms, and the conviction of the kind and degree of sex consciousness found in the many hundreds of analyzed cases, constitute the very essence of the neurotic and psychotic cases, but that conscious and unconscious sex factors are slight or absent in most normal cases; that these patients and their doctors alike are sex-intoxicated, and that the Freudian psychology applies only to perverts and erotomaniacs or other abnormal cases. To ascribe all this aversion on their part to social and ethical repression is both shallow and banousic, for the real causes are both manifold and deeper. They are part of a complicated protest of normality, found in all and even in the resistance of subjects of analysis, which is really a factor basal for self-control, of the varying good sides of which Freudians tell us nothing. The fact is that there are other things in the human psyche than sex and its ramifications. Hunger, despite Jung, fear despite Sadger, and anger despite Freud, are just as primary, aboriginal and independent as sex, and we fly in the face of fact and psychic experience to derive them all from sex, although it is freely granted that in morbid cases each may take on predominant sex features. I think a glance will show how the Freudian mechanisms apply quite as well to anger as to sex.

(1) Anger in most of its forms is the most dynamogenic of all the emotions. In paroxysms of rage with abandon we stop at nothing short of death and even mutilation of the corpse. The Malay running amuck, Orlando Furioso, the epic of the wrath of Achilles, hell-fire, which is an expression of divine wrath, are some illustrations of its power. Savages work themselves into frenzied rage in order to fight their enemies. In many descriptions of its brutal aspects, which I have collected, children and older human brutes spit, hiss, yell, snarl, bite noses and ears, scratch, gouge out eyes, pull hair, mutilate sex organs, with a violence that sometimes takes on epileptic features and which in a number of recorded cases causes sudden death at its acme, from the strain it imposes upon the system. Its cause is always some form of thwarting wish or will or of reduction of self-feeling, as anger is the acme of self-assertion. The German criminalist, Friedrich, says that probably every man might be caused to commit murder if provocation were sufficient, and that those of us who have never committed this crime owe it to circumstances and not to superior power of inhibition. Of course it may

be associated with sex but probably no human experience is *per se* more diametrically opposite to sex.

Some temperaments seem to crave, if not need, outbreaks of it at certain intervals, like a certain well-poised lady, so sweet-tempered that everybody imposed on her, till one day at the age of twenty-three she had her first ebullition of temper and went about to her college mates telling them plainly what she thought of them. She went home rested and happy, full of the peace that passeth understanding. Otto Heinze, and by implication Pfister, think nations that have too long or too assiduously cultivated peace must inevitably, sooner or later, relapse to the barbarisms of war to vent their instincts for combat, and Crile thinks anger most sthenic, while Cannon says it is the emotion into which most others tend to pass.

It has, of course, been a mighty agent in evolution, for those who can summate all their energies in attack have survived. But few if any impulsions of man, certainly not sex, have suffered more intense, prolonged or manifold repressions. Courts and law have taken vengeance into their hands or tried to, and not only a large proportion of assaults, but other crimes, are still due to explosions of temper, and it may be a factor in nearly every court case. Society frowns on it, and Lord Chesterfield says the one sure and unfailing mark of a gentleman is that he never shows temper. Its manifestations are severely tabooed in home and school. Religion teaches us not to let the sun go down upon our wrath and even to turn the other cheek, so that we go through life chronically afraid that we shall break out, let ourselves go, or get thoroughly mad, so that the moment we begin to feel a rising tide of indignation or resentment (in the nomenclature of which our language is so very rich, Chamberlain having collected scores of English expressions of it), the censorship begins to check it. In many cases in our returns repression is so potent from long practice, that the sweetest smile, the kindest remarks or even deeds are used either to veil it to others, or to evict it from our own consciousness, or else as a self-inflicted penance for feeling it, while in some tender consciences its checked but persistent vestiges may become centers of morbid complexes and in yet other cases it burrows and proliferates more or less unconsciously, and finds secret and circuitous ways of indulgence which only psychoanalysis or a moral or religious confessional could trace.

(2) Anger has many modes of *Verschiebung*, both instinctive and cultivated. One case in our returns carries a bit of wood in his vest pocket and bites it when he begins to

feel the aura of temper. Girls often play the piano loudly, and some think best of all. One plays a particular piece to divert anger, viz., the "Devil's Sonata." A man goes down cellar and saws wood, which he keeps for such occasions. A boy pounds a resonant eavespout. One throws a heavy stone against a white rock. Many go off by themselves and indulge in the luxury of expressions they want none to hear. Others take out their tantrum on the dog or cat or perhaps a younger child, or imprecate some absent enemy, while others curse. A few wound themselves, and so on, till it almost seems, in view of this long list of vicariates, as if almost any attack, psychic or physical, might thus be intensified, and almost anything or person be made the object of passion. Be it remembered, too, that not a few look, do, think, feel their best under this impulsion.

(3) Besides these modes of *Abreagierung* there are countless forms of sublimation. In anger a boy says: I will avenge myself on the bully who whipped me and whom I cannot or will not whip, by besting him in his studies, class-work, composition, or learn skillful stunts that he cannot do, dress, or behave better, use better language, keep better company, and thus find my triumph and revenge. A man rejected or scorned by a woman sometimes makes a great man of himself, with the motivation more or less developed to make her sorry or humiliated. Anger may prompt a man to go in to win his enemy's girl. A taunt or an insult sometimes spurs the victim of it to towering ambition to show the world and especially the abuser better, and to be able to despise him in return; and there are those who have been thus stung to attempt greatness and who find the sweetest joy of success in the feeling that by attaining it they compensate for indignities they suffered in youth.

In fact, when we analyze ambition and the horror of *Minderwertigkeit* that goes with it, we shall doubtless find this factor is never entirely absent, while if we were to apply the same pertinacity and subtlety that Jung in his "*Wandlungen*" has brought to bear in working over the treacherous material of mythology, we might prove with no less verisimilitude than he has shown the primacy of the libido that in the beginning was anger, and that not Anaxagoras' love or the strife of Heraclitus was the *fons et origo* of all things, that the *Ichtrieb* is basal, and that the fondest and most comprehensive of all motives is that to excel others, not merely to survive, but to win a larger place in the sun, and that there is some con-

nection between the Darwinian psychogenesis and Max Stirner and Nietzsche, which Adler has best evaluated.

(4) Anger has also its dreams and reveries. When wronged the imagination riots in the fancied humiliation and even tortures of an enemy. An object of hate may be put through almost every conceivable series of degradation, ridicule, exposure and disgrace. He is seen by others for what our hate deems him to be. All disguises are stripped off. Children sometimes fancy a hated object of anger flogged until he is raw, abandoned by all his friends, an outcast, homeless, alone, in the dark, starving, exposed to wild animals, and far more often more prosaic fancies conceive him as whipped by a parent or stronger friend, or by the victim himself later. Very clever strategies are thought out in detail by which the weaker gets even with or vanquishes the stronger, and one who suffers a rankling sense of injustice can hardly help day-dreaming of some form of come-uppance for his foe, although it takes years to do it. In these reveries the injurer in the end almost always gives up and sues for mercy at the feet of his quondam victim. So weird and dramatic are these scenes often that to some minds we must call anger and hate the chief springs of the imagination. A pubescent girl who was deeply offended went off by herself and held an imaginary funeral of her enemy, hearing in fancy the disparaging remarks of the bystanders, and when it was all over and the reaction came, she made up with the object of her passion by being unusually sweet to her and even became solicitous about her health as fearing that her revery might come true. We all too remember Tolstoi's reminiscences when, having been flogged by his tutor, he slunk off to the attic, weeping and broken-hearted, and finally after a long brooding resolved to run away and become a soldier, and this he did in fancy, becoming corporal, lieutenant, captain, colonel. Finally came a great battle where he led a desperate charge that was crowned with victory, and when all was over and he stood tottering, leaning on his sword, bloody and with many a wound, and the great Czar of all the Russias approached, saluted him as saviour of his fatherland and told him to ask whatever he wanted and it was his, he replied magnanimously that he had only done his duty and wanted no reward. All he asked was that his tutor might be brought up and his head cut off. Then the scene changed to other situations, each very different, florid with details, but motivated by ending in the discomfiture of the tutor. In the ebb or

ambivalent reaction of this passion he and the tutor got on better.

Richardson has collected 882 cases of mild anger, introspected by graduate students of psychology, and finds not only over-determination, anger fetishes and occasionally anger in dreams with patent and latent aspects and about all the Freudian mechanisms, but what is more important, finds that very much of the impulsion that makes us work and strive, attack and solve problems has an element of anger at its root. Life is a battle and for every real conquest man has had to summate and focus all his energies, so that anger is the acme of the manifestation of Schopenhauer's will to live, achieve and excel. Hiram Stanley rather absurdly described it as an epoch when primitive man first became angry and fought, overcoming the great quaternary carnivora and made himself the lord of creation. Plato said anger was the basis of the state, Ribot made it the establisher of justice in the world, and Bergson thinks society rests on anger at vice and crime, while Stekel thinks that temper qualities should henceforth be treated in every biography and explored in every case that is psychoanalyzed. Hill experimented with pugilism, and Cannon pleads for athletics as a legitimate surrogate for war in place of James' moral substitute. Frank Howard's opinion is that an impulse that Darwin finds as early as the sixth week and hardly any student of childhood later than the sixth month, should not be repressed but developed to its uttermost, although carefully directed to worthy objects, and he pleads for judicious scolding and flogging, to be done in heat and not in cold blood, and says that there is enough anger in the world, were it only rightly directed, to sweep away all the evils in it. In all these phenomena there is no trace of sex or any of its symbols, and sadism can never explain but must be explained by it.

In this very slight paper I am only trying to make the single point which I think fear and sympathy or the gregarious or social instinct would still better illustrate, although it would require more time, that the movement inaugurated by Freud opens up a far larger field than that of sex. The unconscious that introspectionists deny, asserting that all phenomena ascribed to it are only plain neural mechanisms, and therefore outside the realm of psychology, the feelings which introspection can confessedly never tell much about and concerning which our text-books in psychology still say so little, are marking a new epoch in this field, and in that the chief merit of Freudianism consists.

MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY

Communicated by E. B. TITCHENER and H. P. WELD

XXIV. ON THE VARIATION WITH TEMPERATURE OF THE PITCH OF WHISTLES AND VARIATORS

By G. J. RICH

We recently had occasion to tune a set of Stern tone-variators by comparison with tuning-forks. When the comparison was repeated, a day or two later, the series proved to be slightly out of tune; and this occurred several times. It was natural to think that the change was due to change in the temperature of the room; and reference to works on physics showed that such a variation in pitch might be the result of variation in temperature. It is the purpose of this paper to show this dependence of pitch on temperature, and to set forth the precautions that must therefore be taken in calibrating a whistle or variator.

In the numerous articles which have dealt with the construction, use, and accuracy of these instruments, the influence of temperature has been neglected; and this in spite of the fact that it has been recognized in discussions of the pitch of organ pipes. Ellis[1] mentions that organ pipes change in pitch with temperature, and (as will be noted later) gives a formula for correction. Galton,[2] in describing his whistles, gives a formula for their pitch, which is, he says, valid for ordinary conditions of temperature. But only three of the later writers recognize that temperature-conditions are not always 'ordinary.' Stumpf and Meyer,[3] speaking of a Galton whistle blown by compressed air, say that the compression-apparatus must not be used for too long a time without interruption, because the temperature of the air-stream will change, and cause a slight change in the tone. Myers[4] records as an objection to the Stern variator its sensitivity to slight changes in temperature. But Appunn,[5] Stumpf,[6] Melde,[7] Schwendt,[8] Schulze,[9] Hegener,[10] and Jones,[11] in discussing the ac-

[1] Helmholtz, *Sensations of Tone*, 1895, 89, footnote.
[2] *Inquiries into Human Faculty*, 1883, 375.
[3] *Ann. d. Phys. u. Chem.* (Wiedemann), 61, 1897, 760; 64, 1898, 409.
[4] *Mind*, N. S., 20, 1911, 285.
[5] *Ann. d. Phys. u. Chem.* (Wied.), 67, 1899, 217.
[6] *Ibid.*, 68, 1899, 105.
[7] *Ibid.*, 67, 1899, 781.
[8] *Archiv für Ohrenheilkunde*, 49, 1900, 1; *Verhandlungen der Gesell. deutscher Naturf. u. Aerzte*, 71, 1900, 369; *Verhandl. d. deutsch. otologischen Gesell.*, 9, 1900, 55.
[9] *Ann. d. Phys.* (Drude), 13, 1904, 1066; 24, 1907, 784.
[10] *Verhandl. d. deutsch. otologischen Gesell.*, 17, 1908, 79; 72.
[11] *Edinburgh Medical Journal*, 11, 1902, 349.

curacy of Galton whistles, make no mention of temperature. In other papers, Schwendt,[12] Schulze,[13] Myers,[14] and Titchener,[15] using Kundt's dust-figures, Quincke's tubes, or sensitive flames in the determination of the pitch of whistles, have made corrections for temperature in the constants used to calculate frequency from the crude data, but have taken no account of a temperature-change in frequency itself. Edelmann,[16] using Kundt's method, makes no correction for temperature, but takes as his constant that for average temperature. Stern,[17] in describing his variators, makes no mention of the dependence of pitch on temperature.

In a Galton whistle, or in any form of piston-whistle, as well as in a Stern variator, we have, of course, a vibrating body of air. For such a body, it follows from the theory of dimensions[18] that frequency is proportional to $\frac{\sqrt{p/d}}{L}$, p being the pressure and d the density of air, $\sqrt{p/d}$ the velocity of sound in air,[19] and L any length of the containing chamber. Inserting an arbitrary constant, we get for N, the frequency of our whistle:[20]

$$N = C\frac{v}{L},$$

where C is constant for all geometrically similar containing chambers.

But v, the velocity of sound in air, changes with temperature. Watson[21] gives the following formula for v_t, the velocity at temperature t, when v_0, the velocity at 0°, is known:

$$v_t = v_0\,(1+.0018t).$$

This gives us:

$$N = C\frac{v_0\,(1+.0018t)}{L}.$$ [22]

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[12] *Arch. f. ges. Physiol.*, 71, 1899, 346; *Ver. d. naturf. Ges. in Basel*, 12, 1900, 149.

[13] *Ann. d. Phys. u. Chem.* (Wied.), 68, 1899, 99; 869.

[14] *Jour. of Physiol.*, 28, 1902, 417.

[15] *Proc. Amer. Phil. Soc.*, 53, 1914, 328.

[16] *Ann. d. Phys.* (Drude), 2, 1900, 469; *Zeit. f. Ohrenheilkunde*, 36, 1900, 330.

[17] *Zeit. f. Psychol.*, 11, 1896, 4; 21, 1899, 361; 30, 1902, 422; *Verhandl. d. physik. Gesell. su Berlin*, 16 Jahrgang (4), 1897, 42; *Psychol. der Veränderungsauffassung*, 1898, 82.

[18] This use of the theory of dimensions is justified by Rayleigh, who employs it for the frequency of strings. *Theory of Sound*, 1877, i, 139. For this method of deriving the formula I am indebted to Dr. J. Slepian of the Department of Mathematics, Cornell University.

[19] Watson, *A Text-Book of Physics*, 364.

[20] Since N is proportional to $\frac{v}{L}$, it is equal to a constant *times* this. The constant we have not determined. It depends on the shape of the containing chamber, and the direction in which the measurement L is taken.

[21] Watson, *op. cit.*, 367.

[22] This is, save for the constants, practically the formula given for the dependence of the pitch of organ-pipes on temperature. Barton, *Text-Book on Sound*, 252.

It remains to show that C and L do not change appreciably with temperature. When a whistle-pipe or variator-cylinder expands with temperature, it does so in all directions, and remains geometrically similar at all temperatures; and we have seen that C is constant under just these conditions. L varies with any linear dimension of the pipe. Now most whistles are made of brass. The coefficient of linear expansion of this metal is .000019.[23] But the coefficient of change of the velocity of sound in air with temperature is, as we have seen, .0018. Thus the change in length is only about one one-hundredth of the change in velocity, and may be considered negligible in comparison with the latter. For other metals, the coefficient of expansion is of the same order.

Since C and L do not change, N must vary directly with v, and must have the same coefficient of change with temperature, namely .0018. This means that the frequency changes .0018 or .18% for each degree of change in temperature, and gives us the following formula for N_a, the frequency at temperature t_a, when we know N_b, the frequency at the temperature t_b:

$$N_a = N_b\,[1+.0018\,(t_a - t_b)\,].$$

By means of this formula we can make any correction for temperature.

Ellis[24] gives a similar formula, for Fahrenheit temperature, in which the coefficient is .00104. If we change this to centigrade by the equation: $1°C = 9/5°\ F$, it becomes .00187, which is practically our coefficient.

Such a variation in pitch is by no means negligible. This is readily seen from the following table, which gives the magnitude of the variation at various parts of the scale for 1° and for 10°. A room is liable to vary in temperature, from day to day, as much as this latter amount.

Pitch in *vs.*	Variation in *vs.*	
	1^o	10^o
100	.18	1.8
500	.9	9.
800	1.4	14.
1000	1.8	18.
5000	9.	90.
10000	18.	180.
30000	54.	540.
50000	90.	900.

Let us now turn to the calibration of whistles and variators. If we are using a graphic method, such as the Marbe smoke-rings, we get a record of actual frequency at the temperature at which the determination is made. But if we are to compare a series of determinations (at different parts of the scale, for example), we must correct for temperature by reducing the frequencies obtained to the

[23] Watson, *op. cit.*, 299.
[24] *Loc. cit.*

frequencies at some standard temperature. This may be readily done by the type of formula given above, namely:

$$N_s = N_T\,[1+.0018\,(t_s - t_T)\,],$$

where t_T = temperature at which determination is made.
t_s = standard temperature.
N_T = frequency determined at temperature t_T.
N_s = frequency at standard temperature t_s.

We may next consider calibration by comparison with a source of known frequency (setting by beats). If we use some source which does not vary with temperature, like a siren, which is dependent only on speed of rotation, we get a direct determination for the temperature at which we are working; and this can be reduced to the frequency at a standard temperature in the manner described above for use with a graphic method. But most of our sources of tone vary with temperature. A tuning fork, which is a usual standard source, varies .000112 of its frequency for each degree of change in temperature.[25] This is about one-twentieth of the variation of a pipe, and may usually be considered negligible in comparison with the latter. If, however, it is desired to make this correction, the temperature for which the frequency of the fork is stated must be known.

But when we compare with another whistle, pipe, or variator, the correction for temperature of the standard is no longer negligible. For all we know about our standard is that it gives a certain frequency at a certain temperature. Now let t_q be the temperature at which our known source has a frequency N_q. Then at the temperature t_T, at which the comparison is made, it will have the frequency N_T ; which, since the instrument is a wind instrument, is given by:

$$N_T = N_q\,[1+.0018\,(t_T - t_q)\,].$$

We set the instrument to be calibrated so that it has this same frequency, N_T. We must then reduce this to N_s, the frequency at the standard temperature, t_s, for which we are going to calibrate our unknown whistle or variator. We proceed as follows:

$$\begin{aligned} N_s &= N_T\,[1+.0018\,(t_s - t_T)\,]. \\ &= N_q\,[1+.0018\,(t_s - t_T)\,]\,[1+.0018\,(t_T - t_q)\,] \\ &= N_q\,[1+.0018\,(t_s - t_T)+.0018\,(t_T - t_q)+(.0018)^2(t_s - t_T)\,(t_T - t_q)\,].- \end{aligned}$$

But the factor $(.0018)^2(t_s - t_T)(t_T - t_q)$ is negligible, and is, in fact, neglected in practice. Therefore

$$\begin{aligned} N_s &= N_q\,[1+.0018\,(t_s - t_T)+.0018\,(t_T - t_q)\,]. \\ N_s &= N_q\,[1+.0018\,(t_s - t_q)\,]. \end{aligned}$$

This expression does not involve t_T, the temperature at which the comparison was made. This means that we can make our comparison regardless of the room temperature, and then calculate the frequency of our unknown source for any temperature we may care to assume (t_s). In the special case, where we want to calibrate our unknown for the same temperature as that for which the known source is calibrated, $t_s = t_q$, and no correction for temperature is necessary. Of course, this all assumes that both sources of tone are blown at the same temperature.

[25] Barton, *op. cit.*, 299.

This independence of the temperature at which the work is done also holds for calibration by the method of Kundt's dust-figures. For the frequency calculated by this method is:[26]

$$N = \frac{v}{2l}$$

where v = velocity of sound in air at the existing temperature
l = distance between nodes.
But this is the frequency given by the whistle; and if it is blown at the same temperature, this is:

$$N = \frac{Cv}{L}$$

therefore

$$\frac{Cv}{L} = \frac{v}{2l}$$

and

$$\frac{C}{L} = \frac{1}{2l}$$

since the velocities are equal, being those of air at the same temperature. This shows us that, in calibrating a wind instrument, the distance between the nodes depends only on the construction of the instrument, and is independent of the temperature, provided that both the dust-tube and the source of sound are at the same temperature. This is, indeed, to be expected; for the frequency of the whistle or variator varies directly as the velocity of sound in air, which is the factor that varies with temperature. And the frequency varies similarly when calculated from the dust-piles. Therefore they both vary together for any change in temperature, and the ratio of the other factors must needs remain constant. This is the same independence of the temperature at which the determination is made that we found in the case of comparison with a wind instrument of known frequency. For any given whistle, we get the same L at any temperature. We may therefore assume that it was obtained at the temperature for which we desire to calibrate our whistle, t_s, and may then calculate accordingly, by the formula:

$$N = \frac{v_s}{2l}$$

where v_s = velocity of sound in air at temperature t_s.

$$v_s = v_0 + 61\ t_s.$$
$$= 33150 + 61 t_s$$
$$= 33150\ [1 + .0018\ (t_s - 0)\ ].$$

All of these methods give us calibrations of our whistle or variator at some standard temperature, t_s. If it is used at some other temperature (t_p), it is merely necessary to correct for that temperature

[26] *Ibid.*, 534.

in order to get the actual frequency. This can be done by the formula:

$$N_p = N_s [1+.0018 (t_p - t_s)].$$

To sum up, it has been shown: (1) that the frequency of a whistle or variator varies appreciably with temperature; (2) that temperature must be taken into account in calibrating one of these instruments; (3) that calibrations at different settings must be reduced to a standard temperature to be comparable; (4) that in calibrating by comparison with another wind instrument the temperature at which the comparison was made need not be considered, since both instruments vary to the same amount with temperature; but that the results of such a comparison are valid only for the temperature for which the standard was calibrated, unless a correction be made; and (5) that in calibrating by Kundt's method the temperature at which the determination is made is likewise of no account, the results being valid for the temperature for which the velocity of sound is taken in computing the frequency. Moreover, (6) formulae have been given for performing the various corrections.

XXV. Visual Quality as a Determinant of Clearness

By J. S. Smith

Are there certain color-qualities which make a special appeal to attention? If, for example, red and yellow were to appear simultaneously in the visual field, should we tend definitely to regard the one and to disregard the other; or, in general, is there any visual quality to which we are predisposed to attend? Gale[1] found that black on a white, and green on a black background are most effective for men, while for women red is the attracting color irrespective of background. But Gale apparently made no attempt to control the time of exposure, or to avoid successive contrast, adaptation, and the space-error. Furthermore, he employed only artificial illumination, and he failed to take introspections. It seemed advisable, therefore, to repeat the experiment.

Method and Apparatus.—We employed the method of paired comparisons. The stimuli were six colors of the Milton Bradley Spectral Scales: red (R), orange (O), yellow (Y), green (G), blue (B), violet (V), together with black (Bk) and white (W). These we mounted in one-inch squares, half an inch apart, on both black and white cards, five by eight inches; the black square was mounted on white, and the white square on black. The stimuli were presented in the Whipple tachistoscope, with an exposure of 160 sigma, in both daylight and artificial light, with dark adaptation. Care was taken that no color should appear in consecutive exposures. Since every color was presented with every other color on each background, there were 21 pairs of stimuli in each set. The cards were also shown inverted, to avoid any space error; so that for each illumination there were 42 observations with each background. Finally, every

[1] H. Gale, *Psychological Studies*, 1900, 55 ff.

series was shown three times over to every observer under all four conditions; that is, every observer made in all 504 judgments.

The observers, Mr. L. G. Meads (*M*), graduate student in psychology, Dr. W. S. Foster (*F*), instructor in psychology, and Miss M. F. Sturges (*S*), student in psychology, were instructed to report which of the colors shown was the more clear; if both were equally clear, they were to report 'equal.' After every series the observer was asked to report his experience in making the judgment of clearness.

Results.—Since every color was shown with every other color thirty-six times on each background and in each illumination, the frequency with which any one color may be judged as more clear varies between thirty-six and zero. The following table shows the frequencies of judgment and the rank-order of judgments, with both backgrounds and both illuminations, for each one of the three observers:

TABLE 1.

	Frequencies							Rank Order						
Black background (daylight)														
	R	O	Y	G	B	V	W	1	2	3	4	5	6	7
F	0	25.5	28.5	20	8	10	34	W	Y	O	G	V	B	R
M	0	24	30	19	12	6	35	W	Y	O	G	B	V	R
S	0	33	28	21	13	6	25	O	Y	W	G	B	V	R
White background (daylight)														
	R	O	Y	G	B	V	Bk	1	2	3	4	5	6	7
F	15.5	23	6	29.5	25	14	13	G	B	O	R	V	Bk	W
M	29	20	0	8.5	23	11.5	34	Bk	R	B	O	V	G	Y
S	9	36	11	27	26	13	4	O	G	B	V	Y	R	Bk
Black background (artificial light)														
	R	O	Y	G	V	B	W	1	2	3	4	5	6	7
F	19.5	31	24.5	14	7	5	25	O	W	Y	R	G	B	V
M	14	28.5	25	17	0	6	35.5	W	O	Y	G	R	V	B
S	26	35	24	13.5	8.5	4	15	O	R	Y	W	G	B	V
White background (artificial light)														
	R	O	Y	G	B	V	Bk	1	2	3	4	5	6	7
F	27.5	15.5	0	17	24.5	13	28.5	Bk	R	B	G	O	V	Y
M	32	18	0	15	18	14	29	R	Bk	B	O	G	V	Y
S	36	25	0	15	23	9	18	R	O	B	Bk	G	V	Y

The following excerpts from the introspective reports afford some indication not only of the nature of the experience but also of the criteria of judgment.

F. "When the exposure comes, one of three things happens: (1) I may really see only one color. This is particularly so where Y and O appear with a color considerably darker (on a white background); the latter is then seen first. (2) I may see both colors simultaneously, and clearness is equal. (3) I may see both colors simultaneously and one is clearer than the other. This is the most common occurrence." (Black background.) "Almost without exception the brighter color has been the clearer." "It seems to be the more intense color that is more clear, *i. e.*, the color which is brighter and more saturated. In general the colors are absolutely more clear." "I think that color on black would be more clear than color on white." "In general the more clear color is also the more distinct color." (White background.) "I have a general impression that attention goes to the more saturated colors and to the darker colors and, judging mostly from black and red, that saturation has greater compelling power than darkness."

M. (Black background.) "I seem to take the brighter color,—the one which was glary. I noticed no tendency to choose any particular color. I thought of a spot just behind the fixation point on the screen, and then I named the color which seemed to force itself upon me, the one which furnished the greater tendency to turn to, to attend to."

S. (Black background.) "Tendency for the light colors to be more clear; O looked shiny and was clearer than R. I remember that on the white background R was clearer." (White background.) "When there was light and dark color, the dark usually stood out; Y never got my attention (with artificial light), V only when darker than the other color. When R appeared with other colors it was seen at once and the others not noticed (the same thing was true when Bk and B appeared with light colors); R and O both seemed persistent, stood out immediately."

Discussion of the results.—The first impression made by the objective results is the large degree of individual difference. Two things are, however, obvious. (1) There was no predisposition for any one hue, which was common to all three observers. (2) The fact that observer *S* judged O as the more clear 129 times out of a possible 144 indicates an individual predisposition for that hue. Since no special predispositions can be clearly made out for the other two observers, and since the experiments with different backgrounds (all other conditions remaining the same) yield divergent results, there must be some factor, other than hue, which conditioned clearness. This conclusion is borne out by the introspective reports; the observers themselves believed that their attention was determined by lighter colors on dark backgrounds, and by darker colors on white backgrounds, and also by differences in chroma. We must therefore inquire as to the relative tint and chroma of the colors under the various conditions.

The arrangement of the stimuli in descending order of *tint* as measured by flicker photometry (the values in degrees of *black*) is as follows:

Daylight Y (22), O (190), G (193), V (282), B (292), R (314).
Artificial light: Y (21), O (114), G (234), V (288), R (301), B (317).

To determine the relative *chroma*, we asked a number of psychologically trained observers to arrange the stimuli in chromatic order

under all the four conditions. There was general agreement for the colors on white, but disagreement for the black background. In both cases the colors fall into certain groups within which discrimination is difficult. With the white background, the descending scale (with the grouping) is for daylight, B, GO, YRV; for artificial light, GO, RB, YV. With black backgrounds the diversity was such that we give the actual judgments (with grouping):

Obs.	Daylight	Obs.	Artificial light
W.	B, O–G–Y, R, V	*W.*	G–R–O, B–Y–V.
B.	B, O–R–G–Y, V	*R.*	G–O–R, Y–B–V.
F.	O–B, G–Y, R, V	*B.*	O–G–R, Y–B–V.
C.	O–Y–R–G–B, V		

The safest conclusion is that, on a black background in daylight, the colors are of the same order of chroma, V alone excepted; while in artificial light they fall into two groups, within each of which the chroma is of the same order. The chroma of B and R seems to be especially sensitive to the objective conditions; while O and G maintain a high and V a low position under all four conditions. A similar result is found with regard to tint; Y and V are of approximately the same tint under both illuminations; G and O, which are nearly equal in daylight, differ by 120° of black in artificial light. These facts account easily enough for a general shift of clearness under the various conditions; but they do not explain the individual differences of judgment in any single series. Since we had no further control of the variable factors, and since the number of judgments is too small to render the differences upon which the rank-orders are based positively significant, our data are inadequate to a quantitative treatment. We can offer only a qualitative and tentative explanation.

We suppose that our observers were differently disposed toward the different factors, and that the dispositions were variously actualized by the objective conditions. For example, *in the experiments in daylight and with a black background, we find a general agreement among observers;* the rank-orders are the same for *F* and *M*, except for a one-place transposition of colors nearly equal in tint; while observer *S* differs from *M* only in the exchange of positions of O and W. Apart from these transpositions, *the reports of all observers reproduce the descending scale of tint.* We have seen that, under the conditions of the series, the colors (V excepted) are of the same order of chroma. The objective conditions would therefore favor predispositions for hue and for light-contrast, and would inhibit a predisposition for chroma. The predilection of *S* for O appears; otherwise, contrast-effect seems to be the sole condition of attention for all three observers. *On the white background, however, chroma apparently becomes more effective;* and there seems to be no reason why, with any given pair of colors, either hue, tint or chroma (or a combination of them) should not be determining, according to the predisposition of the observer at the moment. If this be true, we might expect disagreement among observers under the conditions of our own experiment.

Summary.—(1) We have found no predisposition for any one hue, common to all observers; we find evidence, however, of a predisposition for a certain range of hues in the case of one observer.

(2) The problem is not so simple as Gale thought it to be. Aside from hue, tint or chroma, or both, may also be effective to determine attention; and the importance of the variable factors depends partly upon objective conditions, and partly upon the predisposition of the observer. The judgments are not difficult; and now that we have some idea of the factors involved, a repetition of the experiment with stricter control of stimuli should yield a satisfactory answer to our general question.

XXVI. A Preliminary Study of Vowel Qualities

By J. D. Modell and G. J. Rich

The experiments reported in this paper were undertaken as a test of Köhler's earlier work with only approximately pure tones. Köhler employed tuning forks as stimuli; and his observers reported that the series of tones ranging from 163 to 4,000 v. d. gave a series of vowel qualities which could be arranged like those of color. Just as in the case of color there is a series of qualities from red through several nuances of orange to yellow, and from yellow a second series to green, and so on, so there runs a series in the phenomenal tone-system from *u* (moon) through *u-o*, *o-u* to *o*, and from *o* through *o-a*, *a-o* to *a* (father), and so on through *e* (prey) to *i* (machine).[1] In later experiments, in which he used Stern variators with interference apparatus, Köhler determined more accurately the pitch of the pure vowels; added those of *s*, *f*, and *ch* to the upper, and of *m* to the lower region of the scale; and concluded that the pure vowels fall regularly in octaves.[2] Since, however, we wished to know whether observers untrained in continental vowels would give the same judgments, and since Köhler himself holds that vowel qualities are to be found in all relatively simple tones, we have restricted our investigation to the preliminary aspects of the problem.

Apparatus.—We used as stimuli four Stern variators which gave a total range of 100-1200 v. d., a piston-whistle of 1072-3400 v. d., and an Edelmann-Galton whistle from 3560 to 5770 v. d. The variators were tuned by beats with König forks, and the two whistles by the Kundt dust-method. In our first experiments the whistles were blown by pressure on a rubber bulb; but since the pressure could not be rigorously controlled, we later actuated all instruments by air from a tank-gasometer. Weights were added, to give sufficient pressure for the high variator and the whistles. A record was kept of the amount of pressure both at the tank and at the mouth of the instrument, since it was found necessary to adjust the amount of pressure for the particular instrument if we were to obtain the best quality of tone. The pressure varied from 1.8cm. of water for the 300-600 variator to 14.0cm. for the Galton and 15.0cm. for the piston-whistle. All instruments were so connected with the tank that they could be instantly actuated at full pressure. There were two sources of error in the apparatus; a constant error of not more than 1%

[1] W. Köhler, Akustische Untersuchungen, II, *Zeit. f. Psych.*, lviii, 1911, 59 ff.

[2] See also *Zeit. f. Psych.*, lxiv, 1913, 92 ff.

when the temperature was 22-23 C., due to imperfections in the variators; and a temperature error, which never exceeded 1.2%, due to changes in the temperature of the room in which the experiments were conducted. In spite of our attempts to perfect the apparatus, the series of tones was not uniform in quality; there was a decided difference in quality between the lowest variator and the next above, between the highest variator and the piston-whistle, and again between the piston and the Galton. Furthermore, the lower and higher tones of the 300-600 variator were weaker than the tones in the middle of its scale. We could not be certain, therefore, that the observer did not associate certain judgments with certain points in the scale.

Method.—A series of 48 stimuli was prepared, in which the tones advanced regularly by intervals of thirds and fourths from 100 to 268, by whole tones from 268 to 536, by semitones from 536 to 3570, and by whole tones from 3570 to 5770 v. d. Ten series, five ascending and five descending, were given alternately to every observer. To avoid habituation, one tone out of its regular order, but within the same range of pitch, was inserted after every four or five stimuli. The judgments on these extra tones became part of the record, but were omitted from the final results. The observers were Dr. E. G. Boring (B), instructor in the department; Mr. F. S. Kleinman (K), student in psychology; Mr. W. F. Edgerton (E), a student untrained in psychological observation; Mr. G. J. Rich (R), graduate student in psychology, and Dr. H. P. Weld (W), assistant professor of psychology. W alone had had training in music and phonetics. Two sets of instructions were employed. The first three observers above mentioned sat in an adjoining room which communicated with the sound-room by a speaking-tube, and were instructed to write down the vowel-sound which they heard. This method was discarded, because from lack of training in phonetics the observers wrote the vowels in many different characters; so that in the end we were forced to have the reports interpreted, in conformity with continental pronounciation, before the judgments could be understood. This difficulty was obviated by the second method. The observer now sat in the room with the apparatus, though in such a position that he could not see it, and was instructed to reproduce the vowel which he heard or (where strict reproduction was vocally impossible) to pronounce the judgment. All observers were given extended practice before the experimental work began. They were told to regard the tone as singing or speaking a vowel to them. We began with *u* and *i*, as Köhler suggests; then added the remaining vowels; and later took many short series of tones at various parts of the scale. We found it necessary also to point out to the observers the American peculiarities of the vowels *a* and *e*, the former being rarely pure, and the latter having a decidedly diphthongal character. The procedure in the experiments proper was as follows. The experimenter gave the ready-signal, and in about two seconds produced the first tone of the series; the duration of the tone was roughly one second; it was repeated two or three times, or oftener if the observer desired; the judgment was recorded, and the apparatus was set for the next observation. The single experiment did not exceed two minutes, and in the later stages of the work a complete series was run off in thirty-five or forty minutes.

Results.—We found that, under the instructions of the experiment, all observers were able to hear vowel qualities in tones; and, with

one exception, all gave results similar to those of Köhler. Aside from *a*, observer E reported no pure vowels; the mixed forms, *u-o*, *o-a*, *a-o*, etc., were reported, however; and it seems probable that habituation carried E beyond the pure vowel to a point at which the new quality appeared. We have attempted to find the pure-vowel values by averaging the pitch-numbers for which he gave a judgment either of the vowel itself (*a*), or of a combination in which the vowel predominated, every such number being weighted according to the number of judgments. For the other observers, the results are the frequencies of the different judgments for every tone of the series. For our present purpose we need consider only the cases in which the judgment was that of a pure vowel. To obtain an average value for every vowel, the frequencies of the tones judged as a given vowel have been averaged, and each one weighted by the number of relevant judgments. The mean variation has then been calculated for each one of these averages, the single values being weighted in the same way. We have also averaged the values of every vowel for all observers, and finally have averaged the M. V. For the sake of comparison, we have worked out by the same method Köhler's results for his first series with himself as observer. All these results are shown in the following table:

	Vowel				
Observer	*u*	*o*	*a*	*e*	*i*
B	229 ± 49	576 ± 46	1057 ± 209	1778 ± 191	3455 ± 293
K	340 ± 48	630 ± 72	1378 ± 194	1875 ± 75	3941 ± 372
E	(273)	(904)	(2425)	(3569)	(4360)
W	267 ± 36	588 ± 62	1233 ± 177	1967 ± 150	4141 ± 355
R	287 ± 36	606 ± 48	1103 ± 122	1997 ± 110	3439 ± 460
Köhler	223 ± 56	468 ± 85	1139 ± 95	2265 ± 233	3480 ± 409
Average of B, K, W, & R	281 ± 33	600 ± 18	1193 ± 113	1904 ± 79	3744 ± 297
Average of M. V. for B, K, W, & R	42	57	175	131	370

No M. V. was computed for observer E, because it would be in no way comparable with those of the other observers. The averages themselves are only very roughly comparable.

If we look at the individual results, we find that the four observers stand in almost the same order as regards the relative position of the different vowels in the scale. K is usually the highest; then come R, W and B. There are only three inversions of this order, one for *a*, and two for *i*. *Some observers, then, tend to place the whole series of pure vowels higher than others.* When we compare the average of the four with Köhler's results, we find that it is somewhat higher for *u*, *o*, *a*, and *i*, and lower for *e*. The M. V. also shows large differences. Considered relatively to one another, the separate values indicate the size of the region over which the pure vowel is heard; but this is, of course, much smaller than the actual size of that region, because the values near the average have the greatest weight.

If we consider the averages of the four observers, *an octave-relation can be made out between u, o, and a, and between e and i, but hardly between a and e.* It is surprising that the M. V. of *e* is smaller than that of *a;* we had expected that *e,* owing to its naturally diphthongal character, would be the more troublesome.

Results of this sort can do nothing toward settling the current controversy regarding the nature of the vowel-sounds. We thought however that, if Köhler's theory is correct, then the fact of vocality ought to appear fairly plainly in tones such as those which we employed, and ought to appear for observers of various type and training. It does appear; and even if the turning-points are in some measure determined by the inequalities of our tonal series, still they are reported as turning-points of vowel-change; the pitch-numbers may have been somewhat shifted, but the vocality remains. Whether Köhler is right or wrong, it is noteworthy that vocality can at all, with this degree of consistency, be heard into or heard out of the tones employed.

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[1] These additional titles bring approximately up to date the *Bibliography* published by the author in this *Journal*, 24, 1913, 508-19. Those who are interested in keeping this bibliography accurate and complete are again invited to call the author's attention to any errors and omissions.

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BOOK REVIEWS

Native Tribes of the Northern Territory of Australia. By BALDWIN SPENCER. With illustrations. London, Macmillan & Co., 1914. pp. xx, 516.

A classic does not repeat itself; and we shall not thrill again as we thrilled to the story of the Arunta. They, alas! are "decimated in numbers and hopelesly degenerate in customs;" indeed, "there are very few parts of Australia now left in which it is possible to study the aboriginal in his natural state." All the more do we owe gratitude to Professor Spencer for this third contribution to Australian anthropology.

The present work is mainly concerned with the natives of Bathurst and Melville Islands, and with the tribes of the Kakadu nation, inhabitating the Coburg peninsula and the district drained by the Alligator Rivers, some hundred odd miles east of Port Darwin. From the Islands comes an account of burial and mourning ceremonies, the most elaborate on record. They are "interesting because they differ so completely from any on the northern mainland and seem to point to the fact that the island natives have either developed these ceremonies among themselves or have derived them from some other people with whom they, but, apparently, not the natives of the mainland, have come in contact." In most respects the islanders are closely allied to the mainland tribes, so that "the existence of these remarkable burial and mourning ceremonies on the two islands is very difficult to understand." Space may be spared for a single detail: the women carry, besides discs and armlets, highly decorated rings (flat discs with the central portion cut out), some of them as much as 15 in. in diameter,—curiously suggestive, therefore, of the wreaths of civilization; and "the whole color-scheme and design of these armlets, discs and rings [which are shown in color] is quite distinct from anything met with on the continent." The Kakadu and allied tribes add to our knowledge of initiation ceremonies, especially by way of a final ceremony known as Muraian, with which is associated the use of a curious array of sticks and stones connected with totemic animals and plants.

These instruments are instructive, as representing a possible stage on the way from copy to convention: "it is well known how copies, taken in succession, one after the other, of an original drawing, become so modified in the course of a relatively small series, that the last bears no resemblance to the original; . . . it is possible that the Muraian objects show us a series that have not as yet become completely conventionalized but are on their way to this."

We recognize the heel of Achilles in the tale of a man "who had not been completely red-ochred. There was just one spot on his foot which had been left untouched, and here . . . a snake had bitten him, . . . in proof whereof he showed me the scar." Our attention is caught, again, by the plate of pot-hole-like depressions in a rock surface, that are "clearly of human manufacture," and yet unlike anything found anywhere else in Australia; "they seem

to be the work of a people inhabiting the country before the present natives came." Finally, mention may be made of the plates of rock and bark drawings (men, animals, and mythical beings or Mormo) included in the chapter on Decorative Art.

Professor Spencer laments that he has lost the cooperation of Mr. Gillen, to whose memory he dedicates, the book. Mr. Gillen's death was, it is true, a serious blow to anthropological science; but the surviving author has well maintained the standard of the two previous works. The chapters deal, in what is now familiar fashion, with social organization, marriage and initiation; totem groups and ceremonial objects; burial and mourning ceremonies, magic and medicine; customs, beliefs, traditions; food restrictions; weapons, clothing, implements and art. An appendix contains vocabularies and language notes. There are 92 photographic reproductions, beside text-diagrams and maps; and there are 36 plates, of which eight are in color. E. B. T.

The Khasis. By P. R. T. GURDON. With an introduction by Sir C. LYALL. Second ed., illustrated. London, Macmillan & Co., 1914. pp. xxiv, 232.

The Khasis inhabit the Khasi and Jaintia Hills, an Assamese district of some 6,000 square miles whose capital is Shillong. They are isolated among an encircling population of Tibeto-Burman stock; and who they precisely are, and where they came from, are still unsettled questions. Their nearest affinity is to the Mon people of Further India, and they may have moved into Assam from the south-east, linguistic evidence is accumulating, but general anthropological data are still to seek.

The Khasis present three distinctive features which recommend them to the anthropologist. "In the first place, their social organization presents one of the most perfect examples still surviving of matriarchal institutions." Secondly, they possess remarkable methods "of divination for ascertaining the causes of misfortune and the remedies to be supplied. . . . It is somewhat surprising to find among them the identical method of *extispicium* which was in use among the Romans, as well as an analogous development in the shape of egg-breaking . . . which seems to have been known to diviners in ancient Hellas." Thirdly, they have "the custom, which prevails to this day, of setting up great memorials of rough stone, of the same style and character as the *menhirs* and *cromlechs* which are found in Western Europe, Northern Africa, and Western Asia." All these things are set forth, with ample illustration and in full detail, by Colonel Gurdon, under the headings of General Description, Domestic Life, Laws and Customs, Religion, Folk-lore (typical folk-tales, in translation and in the original, are given). Miscellaneous (naming of parents from children; method of calculating time; characters and customs of the Lynggams), and Language. Three appendices deal with the exogamous clans of the Cherra and Khyrim states, and with divination by egg-breaking.

The work was first published, as a government monograph, in 1907. It has now been brought up to date, especially upon the side of language, furnished with a bibliography, and illustrated by ten colored plates from water-color drawings. The book further contains a map, and a number of photographic reproductions. It is a member of the series which contains Colonel Shakespear's monograph on the Lushei Kuki Clans (this JOURNAL, xxiv., 287).

Orchestration. By C. FORSYTH. London, Macmillan & Co.; New York, The Macmillan Co., 1914. Pp. xi, 517.

This work, a volume in The Musician's Library, is written as a guide to students of music who are composing for the orchestra. The author's plan is "first, to describe our modern orchestral instruments, where they sprang from, how they developed, and what they are to-day; next, to trace the types of music which have been reflected in these constructional changes and, in especial, the types most familiar since Beethoven's time. Without some knowledge on these points the student is working in the dark." "The main-lines of study concern the original type of instruments, then its modifications, and last its use in its present-day perfection,—or in some cases, one must say, very partial perfection. A good deal of space has been devoted to explaining the String-technique. This is a subject not often studied from the outsider's point of view." The book opens with a list of instruments and a table of compasses; next comes an introductory chapter on classification; and then the four principal divisions of the work take up, in order, the instruments of percussion, the brass, the wood-wind and the stringed instruments. The writing, though condensed, is clear, and leavened with a pleasant touch of humor; there are nearly 300 illustrative excerpts (more or less compressed) from modern scores. I am not competent to appraise the volume on its technical side; but I have found it useful and interesting from the side of the psychology of music; it is, indeed, precisely the type of technical work upon musical composition that the psychologist needs. The author never loses sight of historical continuity; and a remark like the following (there are many such remarks) is illuminative: "a seventeenth-century Horn-player, if we could resuscitate him, would probably be considerably astonished at the Horn-playing which he would hear at a present-day Symphony-concert. But if he were a good Horn-player, it would not be many weeks before he would be quite competent to 'make one' in the orchestral quartet." There are also many valuable observations upon the feelings, simple and subtle, aroused by instrumental color and by phrasing. I do not hesitate to recommend the book to experimental psychologists. A second edition might be improved by the addition of a systematic bibliography. E. B. T.

An Introduction to General Psychology. By R. M. OGDEN. London, Bombay, Calcutta, and Madras, Longmans, Green and Co., 1914. Pp. XVIII, + 270.

As an apology for lengthening the list of textbooks in psychology, the author acknowledges two principal motives: (1) to furnish a general elementary text which will "supply the student with the sort of introduction into the science of mind that will enable him, on the one hand, to connect his psychology with everyday life, and, on the other hand, to apprehend the bearings of this science upon philosophy, education, sociology, and biology," and (2) to act upon the "conviction that the time has come when we must modify some of our psychological principles and conceptions, with reference to the more recent investigations of the thought-processes."

In regard to the first motive it must be admitted that the author is in good company. The last few years have shown unmistakable indications of a tendency to make the science of psychology less abstract and to reinstate the system of values which obtains in experiences of common life. The problem as to the wisdom of de-

ferring to the interests of students in the questions of the day, or of presenting scientific facts for their own sake in the uncouth rigor of the science, an author must solve for himself. Personally, the reviewer believes that a compromise may be made by studiously selecting as illustrations of the facts and laws of the science those incidental experiences of daily life which most easily lend themselves to such interpretation. Under this sort of treatment psychology would certainly be spared the fate of being required to masquerade in the ill-fitting garments of other disciplines.

With respect to the second motive, the reviewer cannot escape the feeling that the dogmatic presentation of thought-elements is still premature. It was but a few years ago that the same author specifically stated his inability to obtain adequate introspective descriptions of continued thought-processes in terms of content. We now find the unconscious *task* and the *determining tendency* either made part of the conscious element, thought, or left unexplained, and the thought-element is presented to us without attributive description or differentiation from other elements. May it not again be said that the explanation for this procedure is to be found in "the unconscious bias of laboratories" directed by adherents of the school to whose founder the present text is inscribed?

In Part I psychology is defined as a study of mental happenings which takes into account (1) structural contents of consciousness, (2) psychophysiological relations, and (3) purposive mental organization and function. Very wisely the final definition of consciousness is left in terms of the entire material of the book. Consciousness has unity, bears personal reference, and may, under certain conditions, be called a soul. The methods which are used to analyze and describe mental life are retrospection, which is the more proper form of introspection, and to some extent the method of behavior. The importance of the *problem*, of the *directive selection* of processes, and of *interpretation* of results in observational description is emphasized.

Part II describes the analytical facts of mind under the usual headings of the sense departments. Some of the queries which arise from the study of these chapters are: (1) Is it consistent to speak of a colorless series as having color tone? (2) Why confine adaptation to local stimulation in vision? (3) Is not 20,000 vd. too low for the average upper limit of tone? (4) Are timbre, mellowness, and shrillness correlative qualities? (5) Is not 'touch' an antiquated rubric for the cutaneous, kinaesthetic, and bodily sense-groups?

In Part III the synthetic facts of mind are considered. Attention depends in part on the nature of mental activity displayed in interest and in part on the nature of mental contents as described in terms of attributive clearness. Other facts of synthesis are memory, perception, ideation, reaction, and emotion. Except for occasional tendencies to introduce epistemological interpretations and to emphasize purposive direction of mental processes, these subjects are treated, for the most part, in a conventional manner.

The book concludes with Part IV, which summarizes the issues of psychology under the topics: 'mind and body,' 'personality,' and 'character.' In this section the author specifically leaves the empirical level of the science for the interpretative and theoretical, and even sallies into the speculative and evaluative realms of some of the philosophical disciplines.

Noteworthy qualities of the text are its clarity of style and its unequivocal diction. The book reads well. In many places, however,

one feels the need of a proportionate balance between chapters and of a careful elimination of contradictory statements, but future editions will doubtless not elicit this negative criticism. It is certain that the book will meet the requirements of a large number of small institutions where psychology is taught less from an experimental point of view than with an aim to provide the elementary student with materials for general culture.

University of Illinois CHRISTIAN A. RUCKMICH.

Psychology, General and Applied. By HUGO MUENSTERBERG. New York and London, D. Appleton and Co., 1914. Pp. xiv + 487.

Another book which aims to present psychology less abstractly and with more regard for the problems of everyday life has appeared among the textbooks of an unusually productive year. After the introductory chapters, the volume is divided into sections on 'causal psychology,' 'purposive psychology,' and 'applied psychology.' A sharp demarcation is made between the first two, viz., between an objective, structural, and causal explanation of mental states and a subjective, meaningful, and purposive interpretation of the mental life of the self.

Under the caption of 'causal psychology,' the author comes to the conclusion that in the realm of conscious states "there is no direct causal connection possible and that it cannot be introduced by the construction of a subconscious mental machinery." The psychologist must recognize "the general postulate that every single mental state be understood as the accompaniment of a special brain process." After a discussion of the scope and methods of causal psychology, a brief account of the neural substrate is, therefore, given. The chapter on 'stimulation,' however, surprises us in that physiological stimulation does not receive so much attention as the heading would indicate; especially is this true of the lower and internal senses. 'Sensation' would probably be the more appropriate title.

The chapter on 'inhibition' gives occasion for discussing the well-known *action theory* in terms of which the facts of attention, apperception, emotion, thought, the *Aufgabe*, and the allied tendencies are here or elsewhere explained. The meaning of a perception is given by the preparation "for an adjusted line of action." This 'motor setting' is also responsible for the varying functions of the idea. But in space perceptions, the motor aspect, which Wundt emphasizes in his genetic doctrine, is held to be secondary to "the central process itself with which the motor reaction starts."

The closing chapters of this section describe personality, individual differences in the social group, and the union, submission, self-assertion, organization, and achievements of individuals. In the second section the purposive life of the individual and of social units is discussed under the separate headings of the soul, meaning, creation, and practical and ideal relations. In the last section the branches of practical, applied psychology are considered in the light of causal and of purposive psychology; but of the two, the reviewer notes the prominence of causal interpretation; in most cases the purposive aspects seem forced and unnatural and the illustrative citations seem to come from descriptive psychology.

The book is written in the author's customary readable style, but at the expense of concise and definite statement. The presentation suggests an enormous generalized fund, and an unusually comprehensive grasp of psychological data, but the absence of footnotes and

precise references often leaves the scientific reader's curiosity unsatisfied and the more mature student without the means to investigate specific problems. An extensive bibliography at the end of the book partially fulfills this need. More than any other book now before the psychological public, this volume shows the bearing of psychology on many phases of daily life and on the more closely allied disciplines. It points out in a very convincing manner that in the subject-matter of general psychology the consideration of the normative functions of the individual and of the social group has a place beside the description of the constitution of mind as a related series of psychic events. And it makes the further important point that the discussion of these two aspects must be kept rigorously separate.

University of Illinois CHRISTIAN A. RUCKMICH.

A First Book in Psychology. By MARY WHITON CALKINS. Fourth revised edition. New York, The Macmillan Co., 1914. Pp. xxi + 428.

To pass through four editions in five years is a record equalled by very few other textbooks of psychology. It is a record indicative of an attempt on the part of the author to incorporate facts brought out in the development of the science, and, since the book stands practically alone in systematically presenting the doctrine of the *self*, the demand for new editions is further significant as a mark of the academic recognition of this interpretation.

In this edition Miss Calkins sets out to make her claim to a 'self psychology' more consistent in that the distinction between the science of mental processes as structural elements and the science of personal selves as related to objects has now been abandoned. The elements of consciousness, a term which has now become synonymous with 'personal attitude' are "constituents of all forms of the relatedness of self to its objects." Moreover, the book may be placed on the library-shelf labelled 'Behavioristic Psychology,' for, on reading some of the inserted passages we find that this relatedness can be interpreted in terms of behavior. "This somebody is not an isolated self but a self which is affected from without and which expresses itself in its behavior. In view of these facts psychology is more exactly defined as science of the self in relation to, or conscious of, its environment." But in the discussion of method, introspective analysis of experience under experimental control is still considered the mainstay of the science. Observation of behavior "belongs to ethics, to social science, and to pedagogy rather than to psychology," and is admitted only in so far as it premises self-introspection for purposes of inference.

The first five chapters deal with perceiving and imagining. These functions differ in that the first involves (1) passivity, (2) reflectively realized community of perceiving in other selves, and (3) relatedness to an object regarded as independently present. They agree in being (1) impersonal in reference to self, (2) particular in reference, and (3) chiefly sensational, rather than affective or relational, experiences. The imaginal types are given as visual, auditory, usually combiined with motor-tactual, tactual-motor, and mixed; verbal types may also be classified into these groups. Perceiving and imagining may be analyzed by introspection into sensational elements, comprising eight large groups, visual, auditory, gustatory, olfactory, pressure, pain, temperature, and strain. Most of these groups contain elementary experiences of quality, intensity, and extensity. But these are

the products of reflective analysis; ordinarily fusions and assimilations are the immediate experiences. There are experiences which are still more complex, such as the consciousness of space, subdivided into the consciousness of apartness, of form, and of position; the consciousness of harmony, of rhythm, and of melody.

For the first time instinct, habit, and learning are considered in the main text. They are forms of bodily reaction under the laws of perceiving and imagining, and constitute ways in which the efficiency of the organism is promoted in terms of its environment. Other chapters on attention, memory, association, recognition, thought, emotion, will, faith and belief, and the religious consciousness, emphasize the relation of the self to its environment, as expressed by 'personal attitudes' which, under analysis, break up into structural elements.

With so much stress placed upon the relation of the self to its surroundings, we begin to wonder whether the author is not still a trifle inconsistent. From this latest presentation it appears that the relation of the self to its environment is best revealed through its behavior, and that introspection is best suited to the analysis of 'structural elements.' But the peculiar and ultimate method of the science of the relation of self to environment is not the method of behavior, but just this method of introspection. One may emphasize the method of description of behavior and then define psychology from this point of view; or one may lay stress upon the method of introspection and proceed to outline an introspective psychology; but, since the method employed to a large extent defines the science and delimits the results obtained, the reviewer does not believe it consistent to divide the accent as indicated. Thus again it happens, as Ruskin observed that "the thoughts of the wisest are little more than pertinent questions."

University of Illinois CHRISTIAN A. RUCKMICH.

The Rational Education of the Will. By PAUL LÉVY. (Translated from the French, ninth edition, by Florence K. Bright.) Occult and Modern Book Center, Boston, 1914. pp. xvi + 241.

The author aims to show, in a manner comprehensive to any reader, how physical and mental diseases may be cured by the patient himself. The fundamental law of psychotherapy is that "every idea is action in a nascent state." After illustrating in detail the manner in which ideas tend to express themselves in action, the author takes up means of cultivating and strengthening auto-suggestion as the most efficient therapeutic method. At the outset the patient should become thoroughly familiar with his own mental and physical condition. He should accustom himself to think of auto-suggestion, and should practice it unceasingly, day by day, learning by his failures and making use of every encouraging emotional state. He should then develop a notion of what he is capable of becoming, and what he is capable of doing, constantly suggesting these things to himself. He should understand and apply the laws of mental and physical hygiene, and the law of habit formation. Training of the will consists in obtaining a systematic control of one's actions and thinking; for the will is the "result of numerous factors,—ideas, sensations and sentiments of all kinds." The will function according to the laws which govern the mind, hence the will is free to act only as it is submitted to these rules. Finally the author cites numerous observations which illustrate the therapeutic value of suggestion in the breaking of habits, in the curing of various

physical and mental disorders, and in the correcting of general moral and intellectual debility.

Although the book has but slight scientific value, and contains but little that is not generally known, it may be commended in that it presents a simple and systematic treatment of the subject, and in that it creditably serves the purpose for which it was written.

Clark University RAYMOND H. WHEELER.

Mentally Defective Children. By ALFRED BINET and TH. SIMON. Translated by W. B. Drummond, with an appendix containing the Binet-Simon tests of intelligence by Margaret Drummond. New York, Longmans, Green and Co., 1914. 180 p.

Although the translation of this book, originally appearing in 1907, is somewhat tardy from the standpoint of those who for the last five years or more have been finding in Binet and Simon their inspiration for clinical and paidological work, nevertheless it is quite worth while from another aspect. It renders more easily accessible to schoolmen in general a book unique in its field. The subtitle, "Guide for the admission of abnormal children into special classes," is enlightening; the aim it implies is kept constantly in mind and only pertinent matters are discussed.

Beginning with a short chapter for orientation in the history of the work with feeblemindedness, and the prevalence and significance of the condition, the authors present a three-fold classification of all abnormals as the mentally defective, the illy-balanced and the mixed groups. From the description given they seem to include under mentally defective the usual group so-called, the illy-balanced approximate the group now recognized as having only dementia tendencies, while the mixed group is made up of those aments having psychotic tendencies also. These groups are minutely characterized, their aptitudes are enumerated and the pedagogic conclusion is drawn that "all instruction given to defectives must be dominated by the question of its practical usefulness."

Since the need of a different kind of education for such children is obvious, educational segregation is the only solution. A systematic procedure for any such selection is necessary and the one here suggested is logical, not unnecessarily complicated and is based upon practical considerations. The first step is the selection of the group suspected of mental retardation. Since adaptability is a sign of potentially normal functioning the child who fails to adapt himself to the educational situation and therefore to pass along through the grades is probably abnormal. Of course a certain amount of retardation may be due to late entrance, illness or other similar causes. With such cases eliminated a list of all other children under nine years of age retarded as much as two years and of all over nine retarded as much as three years in the grades forms the group to be submitted to individual examination.

This examination is divided into three parts. First comes a pedagogical examination. Here are given Vaney's tests of reading, arithmetic and dictation ability with directions for their use, together with norms. These, with the exception of the arithmetic tests, would doubtless need evaluation because of language differences before they could be used on English-speaking children. The second examination is psychological. The then unfinished measuring-scale of intelligence of the authors is presented in its partial formulation and throws some

illumination upon the question as to how and why the scale was made. The medical examination is limited to an attempt on the part of the physician to discover the causes and possible alleviation of the condition already determined as abnormal by the two examinations mentioned above.

The fact is also emphasized that the value of the special school can not be determined accurately until extensive records are kept of the condition of pupils upon entrance and at regular intervals afterwards. The necessity of following the career of the pupil after he leaves the school is also emphasized.

The book is not purely scientific but scientifically practical and is an illustration of its closing statement that "methods of scientific precision must be introduced into all educational work."

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BOOK NOTES

The feelings of man, their nature, function and interpretation. By NATHAN A. HARVEY. Baltimore, Warwick & York, 1914. 276 p.

One takes up this book today with very great expectations, for the nature, function, and interpretation of feelings might be called, if not the chief theme of psychology in the present, the one sure to be so very soon. In sixteen chapters the author discusses the meaning of the terms and theories of feeling, expression, property, classification, aesthetics, relation to intellect, relation to consciousness, to memory, to attention, to will, to the ego, and finally discusses mental ontogeny. But one cannot resist the query what this author has been doing and how he has managed apparently to escape knowledge of the really epoch-making work done in this field in recent years. It is one thing to make a *chablone* for practical use in the schools, and another really to deal with a subject in a scientific way. Is it possible that we are developing, in this country, a normal school level of intelligence, ability, scholarship, or a normal school edition of knowledge? Let us hope not. I cannot conceive that there is anything in this book for the psychologist.

The fundamentals of psychology; a brief account of the nature and development of mental processes. By BENJAMIN DUMVILLE. Baltimore, Warwick & York, n. d. 382 p.

The writer first discusses the need of psychology as a basis of education, then the relations of mind to body, analysis of phenomena of sensation, perception, imagination, ideation (the latter in three chapters). Then come memory, conation, feeling, instincts and innate tendencies, nature and development of the sentiments, the will, and attention. The book cannot be said to be well gotten up in type, paper, or binding. Why should teachers not have the best there is in the lines they take up?

The psychological methods of testing intelligence. By WILLIAM STERN. Translated from the German by Guy Montrose Whipple. Baltimore, Warwick & York, 1914. 160 p.

It was a very happy idea of Professor Stern to condense his important work in this field into a brief handbook, and also of Professor Whipple to translate it. Here will be found just what a great many psychologists and teachers desire to know. After a brief introduction, discussing the problem of intelligence testing, the author passes to the single tests, taking up in detail the Binet-Simon method, its resultant values, its application to normal children, etc. Here the author discusses the general distribution of the levels of intelligence, age, nationality, social strata, school performance, sex differences, repeated tests with the same children. He then discusses abnormal children and the point of view of reorganization and improvement of gradation methods; the examination and testing of other gradations of intelligence come last.

Children's perceptions; an experimental study of observation and report in school children. By W. H. WINCH. Baltimore, Warwick & York, 1914. 245 p.

This is a book that is both timely and valuable. We have here various series of experiments, in school A on the work of children three, four, five, six and seven years old, and practically the same in school B. Then the work of different standards of boys and girls is considered, with a general chapter on the evolution of children's perceptual judgments. The writer then discusses how far the relative inferiority of the older children is due to differences in the methods of reporting, and gives a summary, with conclusions, and a statistical appendix.

What ought I to do? An inquiry into the nature and kinds of virtue and into the sanctions, aims, and values of the moral life. By GEORGE TRUMBULL LADD. New York, Longmans, Green & Co., 1915. 311 p.

What should I believe? An inquiry into the nature, grounds and value of the faiths of science, society, morals and religion. By GEORGE TRUMBULL LADD. New York, Longmans, Green & Co., 1915. 275 p.

In the first of the above volumes the author discusses the meaning of this question, whence comes the message "I ought," the intention of being good, doing one's duty, feeling I can, the worth of the moral ideals, many or one virtue, custom, law and the moral law, settling questions of conscience, the final issue, morality and religion.

In the second volume the author discusses guessing, "trowing," and believing, the will to believe, less and great beliefs, right and obligation to believe, comforts and rewards, right of belief, beliefs scientific and social, faiths of morality and of religion.

Froebel as a pioneer in modern psychology. By E. R. MURRAY. Baltimore, Warwick & York, 1914. 230 p.

This book was written with a notion that Froebel has not yet come to his own but will surely do so because his thought is so profound. He is said to have anticipated modern psychology, in his analysis of mind, his conceptions of early manifestations of will and consciousness, in the place he assigns to action in the development of apperception and feeling, instincts, play and work. The author gives an evaluation of Froebel's weak points and an answer to criticism, and in an appendix the meaning of activity is discussed. Perhaps he makes out as good a case as can be made for this mystic, whose intuitions and feelings were so deep but who really expresses so little. The author refuses to admit that almost everything in Froebel has been utterly superseded by modern child study, while it has steadfastly arraigned itself in opposition to this work.

Die Grundlagen der Psychologie. Von THEODOR ZIEHEN. Leipzig, B. G. Teubner, 1915. 2 v.

Ziehen begins with the epistemological basis of psychology, then discusses the *Gignomene* and its relations to the general principle of immanence. He seeks to comprehend psychic phenomena under the idea of the soul, to define its relations to the brain, the conscious and unconscious, and the relation of psychology to other sciences.

In the second volume the author follows what he calls the autochthone method, and describes this kind of psychology, working out its relations to apperception, *Vorstellung*, generalization, comparison, combination, inference, judgment, association, feeling-tone, will processes, etc.

Educational guidance; an experimental study in the analysis and prediction of ability of high school pupils. By TRUMAN LEE KELLEY. New York, Teachers College, 1914. 116 p.

This is a valuable contribution to a question of growing practical interest. How far is success in the grades evidence of high school ability, what is the relation of teachers' estimates to tests in the different departments or topics, and the culmination of tests with reference to the different topics? This book also discusses the factor of pupils' age, the comparison with other studies, practical application in high school classification, and guidance methods.

Variation in the achievements of pupils; a study of the achievements of pupils in the fifth and seventh grades, and in classes of different sizes. By CHARLES HERBERT ELLIOTT. New York, Teachers College, 1914. 114 p.

Here we begin with data based on tests of scorings in spelling and writing, composition, vocabulary, arithmetic, and other data. Then standards of achievement for the fifth and seventh grades, attainments in class, measurement of class size, are discussed, with an appendix directing how to administer these tests, samples of others, preliminary list of composition subjects, notes, and a bibliography.

American thought from puritanism to pragmatism. By WOODBRIDGE RILEY. New York, Henry Holt & Co., 1915. 373 p.

This volume treats of puritanism, early idealism, deism, materialism, realism, transcendentalism, evolutionism, modern idealism, and pragmatism. It is a useful introduction and will give the novice a helpful orientation, though it is extremely incomplete, with surprising gaps, and, as such a theme must inevitably do, displays the lines of both the author's reading and his ignorance, his likes and dislikes.

Buddhist psychology; an inquiry into the analysis and theory of mind in Pali literature. By MRS. C. A. F. RHYS DAVIDS. London, G. Bell & Sons, Ltd., 1914. 212 p.

This book contains nine chapters. The first is entitled Habits of Thought, while the following are devoted to the Psychology of the Nikavas. 1. On Mind in Term and Concept; 2. Consciousness in the External World; 3. Feeling; 4. and 5. Ideation. Then follows a chapter on Psychological Developments in the Pitaka. Chapter 8. is on Psychology in the Milinda. Then follow some mediaeval developments.

Einführung in die experimentelle Psychologie. Von N. BRAUNSHAUSEN. Leipzig, B. G. Teubner, 1915. 111 p.

This tiny primer treats of the history, justifications, and aids of experimental psychology, the psychic structures, sensation, intensity, Weber's law, apperception, judgment, *Vorstellung*, association, memory, *Aussage*, fantasy, attention, tests of intelligence, fatigue, aesthetics, will.

Stephan Witasek was professor at the University of Graz. He published various papers on spatial perception, on learning and on other topics (one in collaboration with Meinong). He was the author of: *Grundzüge der allegemeinen Aesthetik,* 1904; *Grundlinien der Psychologie,* 1908; *Psychologie der Raumwahrnehmung des Auges,* 1910. In collaboration with A. Höfler, he published: *Psychologische oder experimentelle Psychologie an Gymnasien,* 1898; *Psychologische Schulversuche,* 1900; *Hundert Psychologie Schulversuche,* 1903.

Ernst Meumann was born August 29th, 1862. He studied under Wundt at Leipzig, where he received the Ph. D. degree in 1889. After serving as Privat Dozent for a time in Leipzig, he was called to Zürich, where he was promoted to the rank of professor in 1900. He was subsequently called to a chair in Königsberg, 1905; Münster, 1907; Halle, 1909; Leipzig, 1910; and to the Kolonialinstitut in Hamburg, 1911. Besides a number of papers on psychological and pedagogical topics, he produced the following works: *Die Entstehung der ersten Wortbedeutungen beim Kinde,* 1902; *Oekonomie und Technik des Gedächtnisses,* 1903; *Hausarbeit und Schularbeit,* 1904; *Vorlesungen zur Einführung in die experimentelle Pädagogik,* 1907; *Intelligenz und Wille,* 1908; *Einführung in die Aesthetik der Gegenwart,* 1911. He was founder and editor-in-chief of the *Archiv für die gesamte Psychologie* (since 1903) and of the *Zeitschrift für experimentelle Pädagogik* (since 1907).